

AD 701942

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DESIGN, DEVELOPMENT, AND TESTING OF  
TIRES FOR 16 TON GOER VEHICLES

FINAL REPORT

CONTRACT NO. DA-33-019-ORD-3478  
(Including Modification 1 - 7)

THE FIRESTONE TIRE & RUBBER COMPANY

AKRON, OHIO

This project was performed under the technical  
supervision of Research & Engineering Directorate,  
Army Tank-Automotive Command.

Cleveland Ordnance District Office  
Ordnance Project No. TW-510  
D/A Project No. 546-09-036

Report Prepared By:

T. J. Lonson  
Tire Engineer

E. S. Sites  
Compounder

Approved By:

*W. H. Christensen*

November, 1963

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Abstract

AD \_\_\_\_\_ Accession \_\_\_\_\_  
Firestone Tire and Rubber Co., Akron, Ohio  
Design and Testing of 29.5-25 tires for  
16 ton Goer Vehicle - T. J. Lonson, E. S. Sites  
December, 1963 - pp - illus - tables

Contract No. DA-33-019-ORD-3478  
D/A Project No. 546-09-036  
Unclassified Report

Earthmoving tires were specifically developed for use on the Goer vehicle. This development work included the design of various tread configurations and use of maximum feasible synthetic content. Tires were produced in three different tread designs, and two different levels of synthetic content. These tires were then tested for running temperature, traction, and mobility. Durability tests of 40% highway, 40% secondary roads, and 20% cross country were conducted. These tests showed that tires could be produced to provide at least 15,000 miles without any premature failures for this type of service.

## OBJECT

The object of the original contract dated 30 September 1960 was to design and develop 29.5-25 16 ply rating tubeless tires to provide optimum performance when used on the Goer vehicle. It was also desired to attain these goals while using the maximum feasible synthetic content.

Subsequent modifications (1-7) from June, 1961 through January, 1963 called for:

1. Non-destructive drum testing.
2. Temperature testing in continuous highway service.
3. Traction testing in various soils.
4. Durability testing on paved (40%) and secondary (40%) roads and off-highway terrain (20%).

## Conclusions:

1. We found that it was possible to produce tires more suited to the requirements of the Goer vehicle than any commercially available tire. The major areas of improvement includes the capacity for continuous highway operation and improved performance in mud. The three designs developed are shown in figures 1-4.

Figure 1 - Super Ground Grip Goer

Figure 2 - Super Ground Grip Goer (Grooved)

Figure 3 - ND-CC Goer

2. Maximum synthetic content of the 29.5-25 SGG Goer was found to be 50% of the polymer used. The maximum synthetic content was determined by an evaluation of compound properties considering separation resistance and wear, cut, chip and tear resistance, as determined through the specific tests performed during the term of this contract and its modifications. However, certain inherent deficiencies from increasing synthetic (relative to natural rubber which is being replaced) in larger Off-The-Road type tires, should be recognized. These are:

### A. Higher Heat Build-Up

To use synthetic in the tread of the tire, it was found necessary to incorporate a cooler-running, high-natural-rubber-content compound in the tread base under an all-synthetic tread cap compound, in order to lower the tire temperature in the critical separation area on top of the tire carcass.

### B. Poor Crack or Cut Initiation and Growth

This deficiency manifested itself quite markedly during the durability testing. As a result of these tests, compound modifications were made in the all-synthetic tread cap stock to improve upon this property for future Goer tires.

### C. Lower Resistance to Chip and Tear

Although the all-synthetic tread cap has been compounded to obtain the maximum cut, chip and tear resistance, without sacrificing other properties, there is an inherent lower resistance relative to natural rubber, for Off-The-Road type service, which compromises the overall performance of the tire. The exterior compounds of the tire (i.e. the tread and sidewall) have adequate protection against atmospheric deterioration and good low temperature

Firestone  
Super Ground Grip Goer  
Directional

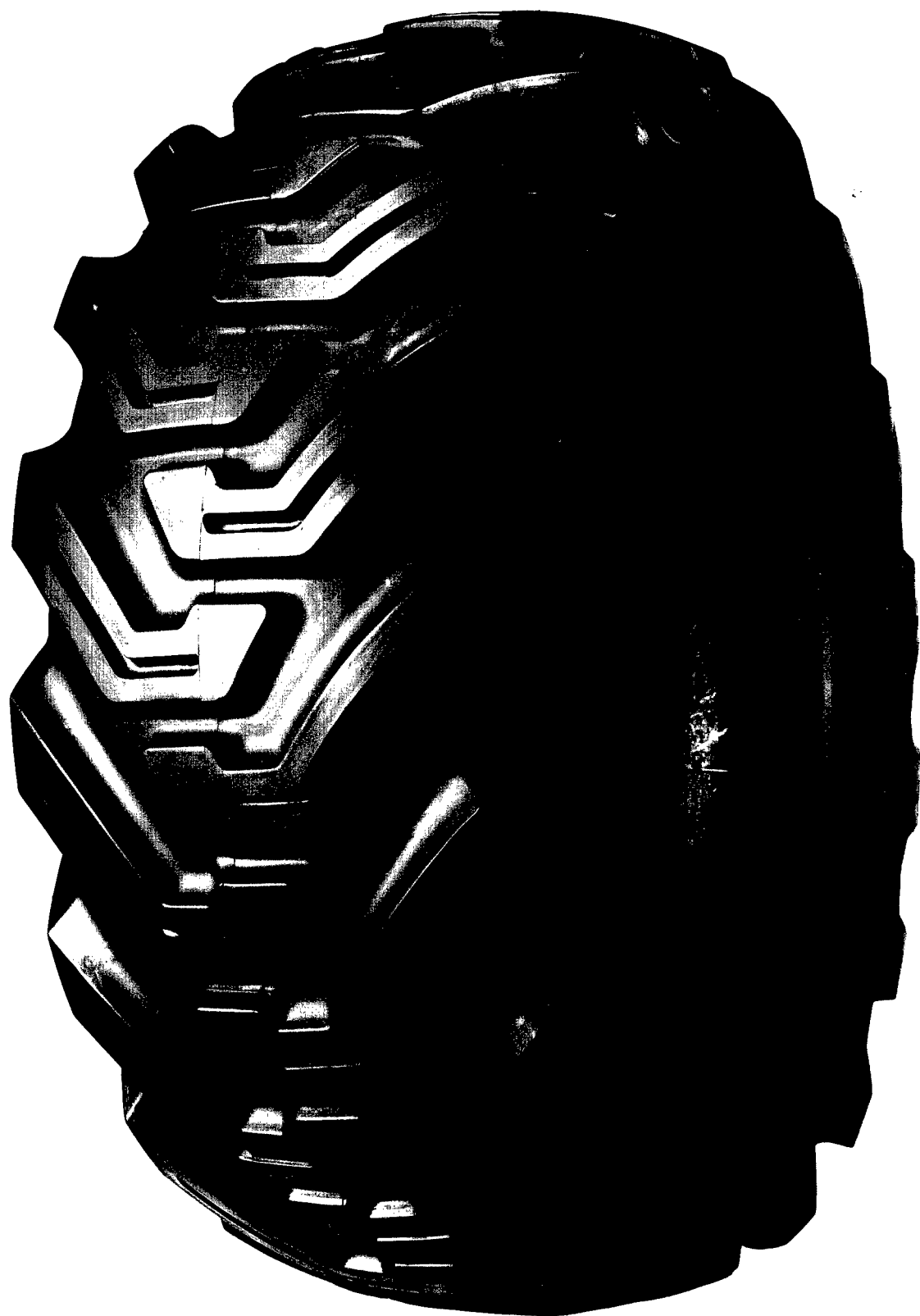
Figure 1



Firestone  
Super Ground Grip Goer  
(with grooves)

Directional

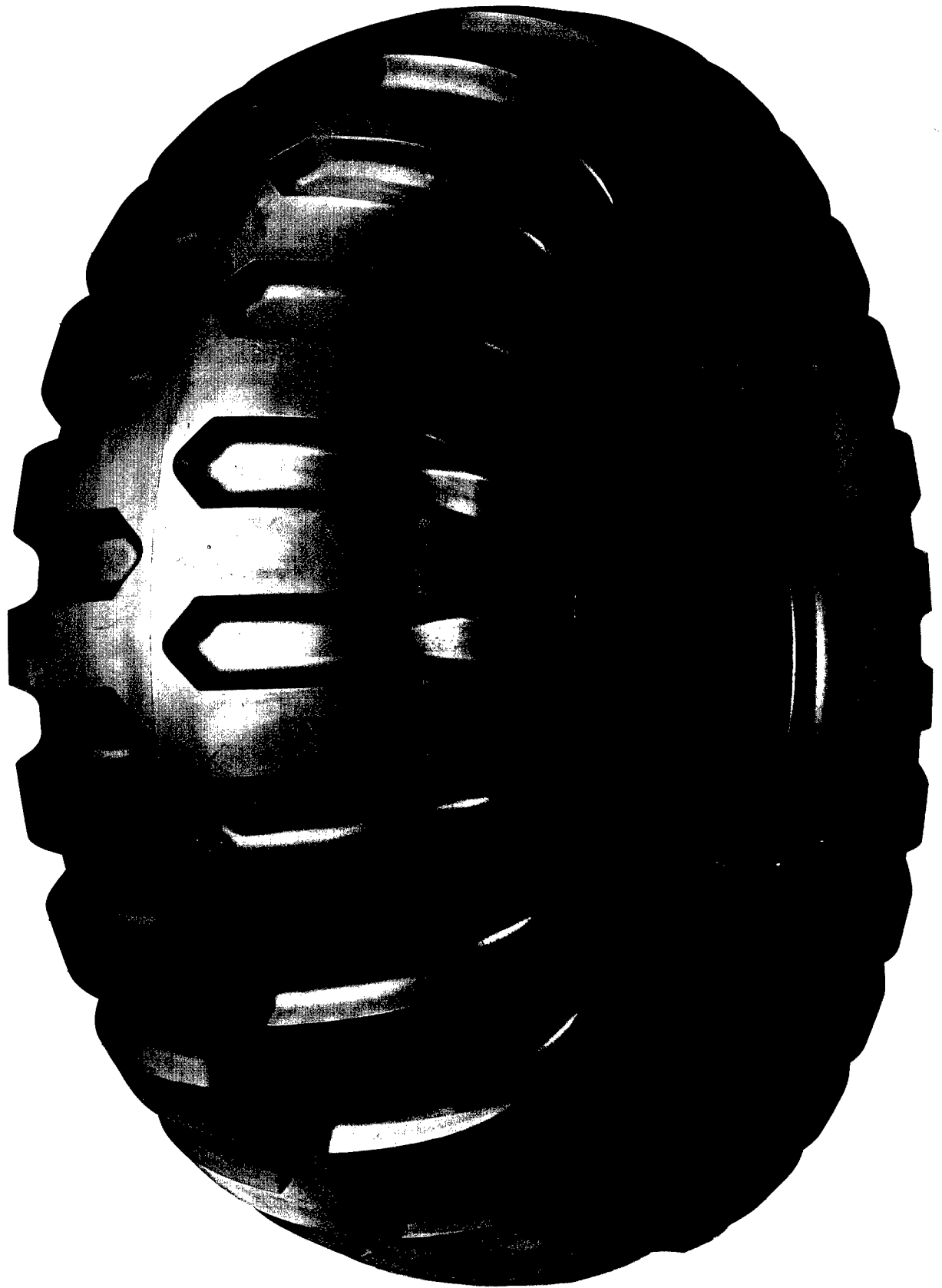
Figure 2



Firestone  
ND-CC Goer  
Non-directional

Figure 3

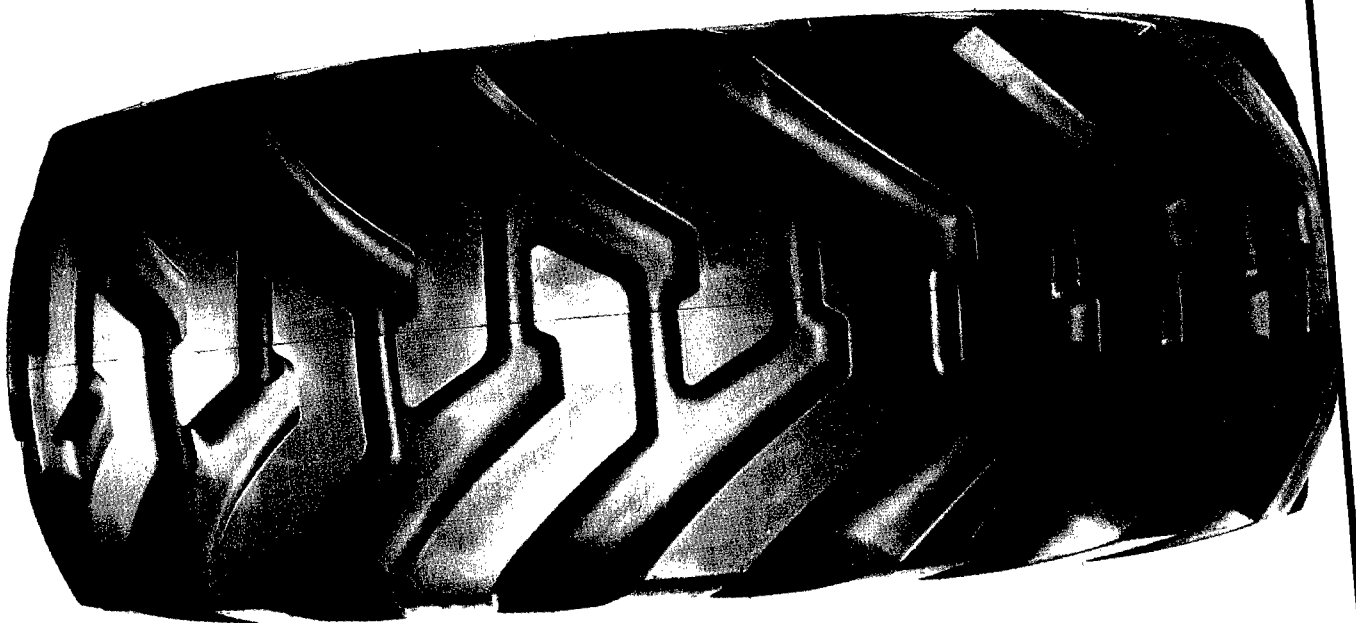
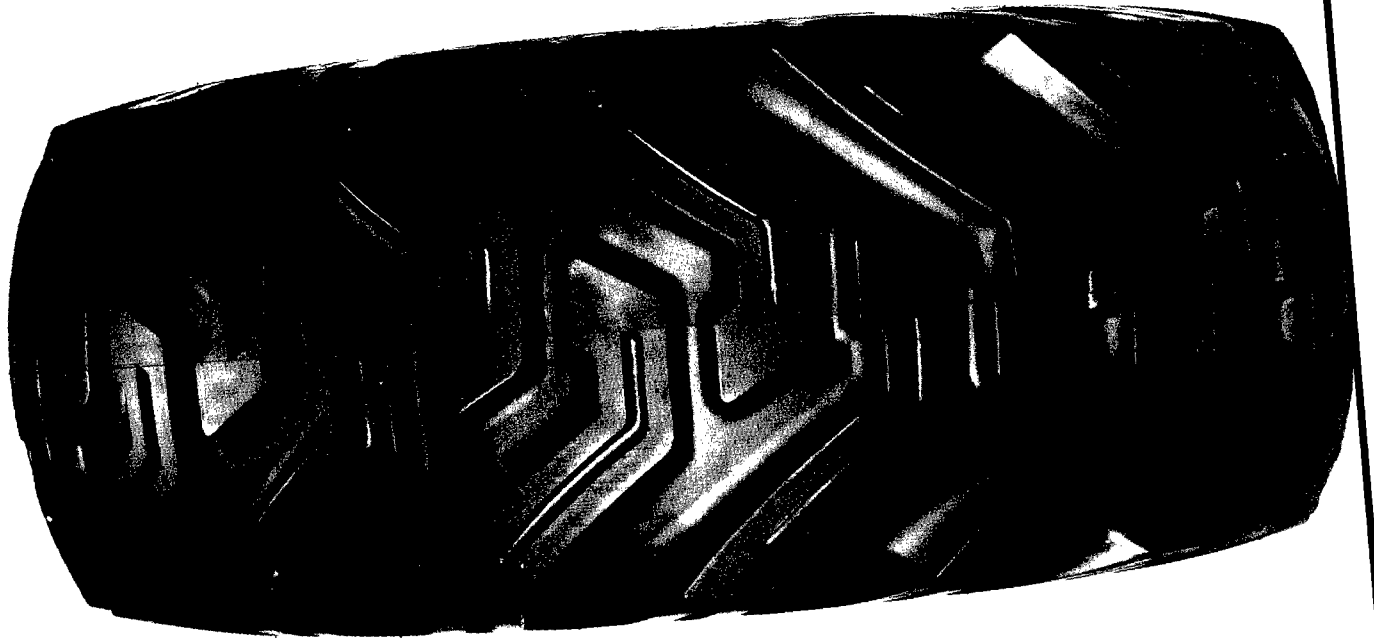
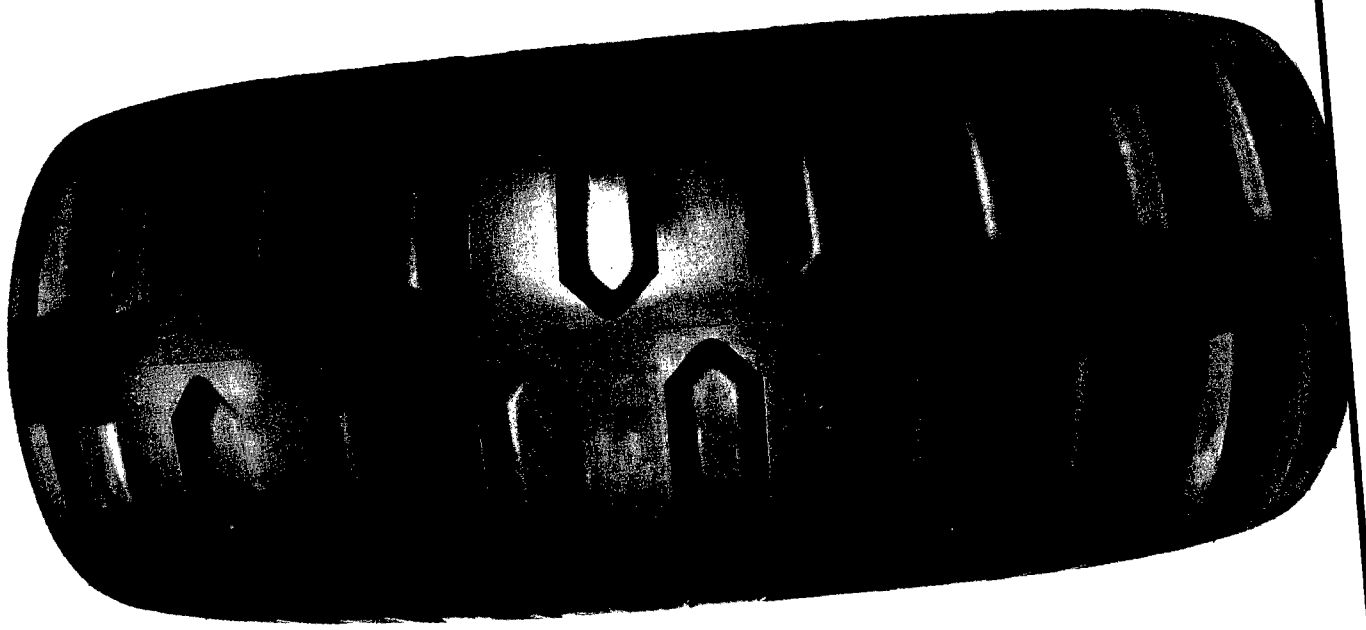




Head-on view of the three test designs  
From left to right-

Super Ground Grip Goer  
Super Ground Grip Goer (with grooves)  
ND-CC Goer

Figure 4.



flexibility as a result of the particular blend of synthetic polymers used.

Use of the protective coatings described under Tire Compounding markedly enhances the tires' exterior compounds' resistance to atmospheric deterioration.

3. Of the three designs developed for this contract, the best design for optimum performance, as determined by these tests, was the Super Ground Grip Goer tire with the grooved tread bars. This was the only tire of the three which would operate at a sufficiently low temperature to allow use of the maximum synthetic rubber construction and still permit continuous highway operation. This design, with or without the tread grooves, is approximately three times as effective in deep mud as the ND-CC Goer design. The ND-CC tire was approximately 10 to 15% more effective for drawbar pull on non-compressible surfaces and compressible soil. There was little difference in the sand performance of any of these designs. Our selection of the grooved Super Ground Grip Goer tire as the optimum was based on the premise that the prime requirement of these tires was the ability to operate continuously in highway service and provide maximum performance in mud.
4. Shown below is a table which summarizes the information obtained from the durability phase of the testing. The significant factors are that no tires were removed due to any type of premature failure. Also, the tires with the synthetic tread had a wear rating double that of the natural rubber tires.

TABLE - DURABILITY TEST SUMMARY

| TYPE                                     | SGG GOER<br>(GROOVED) | SGG GOER<br>(GROOVED) | ND-CC GOER      |
|--|-----------------------|-----------------------|-----------------|
| Compounding                              | Natural Rubber        | Synthetic Rubber      | Natural Rubber  |
| Average Test<br>Miles Per Tire<br>Sample | 10,022                | 15,040                | 7,509           |
| Reason for Removal                       | Worn Smooth           | Worn Smooth           | Test Terminated |
| Durability Rating                        | 100                   | 150                   | Not Available   |
| Tread Wear, Average<br>Miles/mil. (1)    | 6.1                   | 12.2                  | 16.3            |
| Tread Wear Rating                        | 100                   | 200                   | 267             |

- (1) See pp. 19-20 of Final Report, Durability Testing - Summary of Tire Tread Wear

It can be concluded from this testing that the Super Ground Grip Goer (grooved) tire with the natural rubber construction will not provide the desired 15,000 mile durability; however, through use of a synthetic construction, this level can be achieved. The ND-CC Goer design should provide approximately 20 to 25,000 miles with the natural rubber construction used, and could possibly double this figure by using the same synthetic compounds used in this test. It must be remembered that we are limited by the operating temperatures also.

## Recommendations

1. Since no one design tested was clearly superior in all of the categories evaluated, it would seem that there is probably some design that would provide better overall performance than either of the three designs tested. It is our recommendation that additional testing be conducted to evaluate other design variations that would improve the mobility of the Goer vehicle.
2. This contract was limited to a tread design and compounding evaluation. It would also be beneficial to conduct tests in an attempt to evaluate the effects of various types of carcass constructions.
3. Use compound modifications to the all-synthetic tread cap compound referred to under conclusion #2 and under Tire Compounding, section B-1. These modifications were incorporated into the tires being fabricated for the European Troop Tests to be conducted in the spring of 1964.
4. Use tire protective Coating A referred to under Tire Compounding, section A-5. This coating has been used on all Goer tires manufactured by Firestone.
5. In view of the promising performance of the high-percentage-synthetic compounds in these tires, in service where natural rubber is normally used, continued compounding studies should be conducted to improve upon the overall performance characteristics of the high-synthetic-bearing compounds.

## Background

Prior to this development contract, special tires were produced in existing commercial molds and supplied for use on the first four Goer vehicles. Design features of these tires were aimed primarily at maximum traction and continuous highway operation.

These tires performed fairly well, but a need was recognized for tires designed specifically for Goer vehicle-type service.

Subsequently, this contract called for production of four tires of each of three different designs. In addition, tires were to be produced with the maximum feasible synthetic content. In order to test these various characteristics, the following five tire specifications were issued and the corresponding tires produced:

| <u>Serial</u> | <u>Type</u>           | <u>No. Tires</u> | <u>% Synthetic</u> |
|---------------|-----------------------|------------------|--------------------|
| K12500        | SGG Goer              | 2                | 11%                |
| K12600        | SGG Goer              | 2                | 52%                |
| K12700        | SGG Goer with grooves | 4                | 13%                |
| K12800        | ND-CC Goer            | 2                | 14%                |
| K12900        | ND-CC Goer            | 2                | 56%                |

Modification 1 dated 22 June 1961 called for one of each of these tires to be tested on an indoor laboratory drum to provide a temperature comparison.

Modification 3 dated 20 September added on-vehicle testing which would include an evaluation of these tires for continuous highway operation, mud, sand, drawbar pull, slopes, and maneuverability. These tests were subcontracted to Le-Tourneau-Westinghouse with ATAC approval. They conducted the highway temperature comparison and the mud tests but the drawbar pull tests in sand, non-compressible surface, and compressible soil were subcontracted by them to Nevada Automotive Test Center, Carson City, Nevada.

Modification No. 7 added a 20,000 mile durability test and twelve additional tires were supplied. Six of these were control tires in the Super Ground Grip Goer (with grooves) design with standard earthmover tire construction and compounding (natural rubber) features. The remaining six tires were the same except that the maximum possible synthetic rubber content was used.

In addition five tires in the ND-CC Goer design were purchased under contract number DA-20-089-ORD-40018. These tires were used as replacements for the durability test. Four of these tires attained 7500 miles before the 20,000 mile test limit was reached.

### Mold Design and Tire Construction Development

The design of the tires for the 16 ton Goer vehicle requires consideration of the following criteria:

1. Gross Vehicle Weight - 64,000 Lbs.  
4 Tires  
58% of load on front axle  
42% of load on rear axle
2. Speed - Maximum over 30 MPH  
Cruise at 20 MPH  
Water at 4 MPH
3. Roadability - Capable of long sustained hauls.
4. Traction - Maximum in mud.
5. Flotation - Good in all soils (mud and sand).
6. Minimum vehicle.  
Ground Clearance - 30"
7. Ozone Resistance - Equivalent of standard military specification requirements.
8. Compounding - Maximum feasible synthetic content.
9. Durability - 25,000 miles.

From the above data, the 29.5-25 size was selected as the optimum tire for use on this vehicle. This will provide the load carrying capacity and ground clearance required, and this wide base profile will provide maximum flotation and traction.

After the size selection was finalized, it was necessary to arrive at the best possible tread configurations. It was originally decided to bring in one tire mold with three separate tread rings; however, upon consideration of factory production engineers, it was decided to fabricate two unicast molds rather than one. Although this increased the cost over the original estimate, the advantages provided both the contractor and the customer decisively outweighed the additional cost to the contractor.

The three tread designs selected were:

1. Super Ground Grip Goer (maximum traction) See figure 1
2. Super Ground Grip Goer with grooves (modified maximum traction). See figure 2.
3. ND-CC Goer. See figure 3



The Super Ground Grip Goer design was similar to our own commercially proven Super Ground Grip WB tire. The purpose of the tread grooves in the modified tire was to reduce the tire operating temperature. Prior experience indicated that this would reduce tire operating temperatures by approximately 15°F.

Design dimensions for the ND-CC Goer were based on Tire and Rim Association limits and design criteria in MIL-T-12459A for cross country type tires.

Shown below is an evaluation of the performance characteristics which we felt could be expected from these three designs:

|                      | <u>Super Ground<br/>Grip Goer</u> | <u>Super Ground<br/>Grip Goer<br/>(with Grooves)</u> | <u>ND-CC Goer</u> |
|----------------------|-----------------------------------|--|-------------------|
| Directional          | Yes                               | Yes  | No                |
| Mud Traction         | Excellent                         | Excellent  | Good              |
| Sand                 | Good                              | Good   | Good              |
| Highway Roadability  | Fair                              | Fair   | Fair              |
| High Speed           | Good                              | Excellent  | Good              |
| Continuous Operation |                                   |  |                   |
| Wear Resistance      | Good                              | Good   | Good              |
| Cut Resistance       | Fair                              | Fair   | Fair              |

In order to carry the required load and yet have the lightest possible construction, a 16 ply rating construction was chosen as the optimum. The load rating for this tire is 17,190 pounds at 25 psi inflation for intermittent operation and 14,520 pounds at 30 psi for continuous highway operation. The weight of these tires is approximately 800 pounds.

The carcass construction utilized 840/2 nylon with a tensile of 30 pounds per cord. These twelve tires were of twin bead construction, 14 actual plies, and two tread plies. They also had an under base of .45". All other features were standard production items with the exception of the compounding.

## TIRE COMPOUNDING

### A. ORIGINAL CONTRACT

#### 1. BASIC REQUIREMENTS FOR GOER TIRE COMPOUNDS

1. COMPOUND STOCK WITH MAXIMUM SYNTHETIC CONTENT
2. COMPOUND STOCKS FOR PROTECTION AGAINST ATMOSPHERIC  
DETERIORATION
3. COMPOUND PROTECTIVE COATING TO COMPARE WITH (2)
4. COMPOUND: BEST COMPROMISE BETWEEN COOL RUNNING TIRE AND  
CUT, CHIP AND WEAR RESISTANT TREAD AND SIDEWALL

2. COMPOUNDS SELECTED FOR FABRICATION OF TIRES

TIRE IDENTIFICATION

29.5-25 16 PLY TUBELESS

|  | <u>SERIAL<br/>IDENTIFICATION</u> | <u>COMPOUND<br/>LINE-UP</u> | <u>% OF POLYMER<br/>AS SYNTHETIC</u> | <u>NO. OF<br/>TIRES</u> |
|--|----------------------------------|-----------------------------|--------------------------------------|-------------------------|
| SUPER GROUND<br>GRIP GOER<br>MAXIMUM TRACTION<br>DESIGN          | K12500                           | I                           | 11                                   | 2                       |
|  | K12600                           | II                          | 52                                   | 2                       |
| SUPER GROUND<br>GRIP GOER<br>MODIFIED MAXIMUM<br>TRACTION DESIGN | K12700                           | I                           | 13                                   | 4                       |
| ND-CC GOER DESIGN  | K12800                           | I                           | 14                                   | 2                       |
|  | K12900                           | III                         | 56                                   | 2                       |

## 2. COMPOUNDS SELECTED FOR FABRICATION OF TIRES

|                            | COMPOUND DESCRIPTION                     |  |  |
|----------------------------|--|--|--|
|                            | <u>LINE UP I</u>                         | <u>LINE UP II</u>                        | <u>LINE UP III</u>                       |
| Tire Serial Identification | K12500, K12700, K12800                   | K12600                                   | K12900                                   |
| Tread                      | NR                                       | Isoprene                                 | Oil Extended FR-S                        |
| Sidewall                   | $\frac{1}{2}$ Neoprene- $\frac{1}{2}$ NR | $\frac{1}{2}$ Isoprene- $\frac{1}{2}$ NR | Oil Extended FR-S                        |
| Outer Body                 | NR                                       | NR                                       | $\frac{1}{4}$ Isoprene- $\frac{3}{4}$ NR |
| Inner Body                 | $\frac{1}{4}$ Diene - $\frac{3}{4}$ NR   | Same as Line Up I                        | Same as Line Up I                        |
| Innerliner                 | 7/10 Chlorobutyl-3/10 NR                 | "  | "  |
| Bead Insulation            | FRS                                      | "  | "  |
| Other Bead Compounds       | NR                                       | "  | "  |

### 3. COMPOUND DESIGN

#### COMPOUND LINE UP I

Compound Line Up I with 11 to 14% of the polymer as synthetic (depending on weight distribution of tire components) is the least deviation from standard Off-The-Road Tire Compounding.

This Line Up features an all natural rubber tread with superior cut and tear resistance. The tread is specially compounded for cool running and resistance to atmospheric deterioration.

The sidewall is compounded from a polymer blend of 50% Neoprene and 50% natural rubber, and is extremely resistant to atmospheric deterioration.

The outer body is compounded from all natural rubber. It is cool running and furnishes maximum tear and heat resistance.

25% of the polymer as Diene and 75% natural rubber is the feature of the inner body. It is cool running and heat resistant.

The innerliner is compounded with 70% of the polymer as chlorobutyl and 30% natural rubber. Excellent heat resistance and impermeability to air are its features. One-half as much air is transmitted at 176°F and 75 psi through this type innerliner than through an all natural rubber innerliner.

#### COMPOUND LINE UP II

Compound Line Up II with 52% of the polymer as synthetic is a greater departure from standard compounding. Its tread polymer is 100% Isoprene specially compounded for best compromise between cool running and resistance to wear, tear and atmospheric deterioration.

The sidewall, compounded from 50% Isoprene and 50% natural rubber, is tear, cut and atmospheric deterioration resistant.

The same compound features as Line Up I are used in the remainder of the tire.

#### COMPOUND LINE UP III

Compound Line Up III, with 56% of the polymer as synthetic, features tread and sidewall compounds with all of the polymer as oil extended FRS, specially compounded for resistance to atmospheric deterioration.

The tread and sidewall are also compounded for cool running and cut and tear resistance.

Isoprene as 25% and natural rubber as 75% of the polymer is the feature

of the outer body. The outer body is compounded for cool running, and heat and tear resistance.

The remaining compounds are the same as Line Up II and III.

#### 4. COMPOUND PROPERTIES

##### TREAD

|                             |                          |              |              |
|-----------------------------|--------------------------|--------------|--------------|
| Compound Line Up:           | I                        | II           | III          |
| Tire Identification Serial: | K12500, K12700<br>K12800 | K12600       | K12900       |
| Formulation:                | 100 NR                   | 100 Isoprene | 131 FR-S 123 |

##### Normal (70°F) Stress-Strain

|                   |      |      |      |
|-------------------|------|------|------|
| Tensile, psi      | 4175 | 3025 | 3075 |
| 300% Modulus, psi | 1750 | 1625 | 825  |
| Elongation, %     | 540  | 480  | 675  |

##### Tensile @ 275°F

|               |      |     |     |
|---------------|------|-----|-----|
| Tensile, psi  | 1100 | 625 | 700 |
| Elongation, % | 320  | 210 | 340 |

##### Normal (70°F) Tensile After 2 Days @ 212°F

|               |      |      |      |
|---------------|------|------|------|
| Tensile, psi  | 2250 | 1275 | 2675 |
| Elongation, % | 250  | 185  | 465  |

##### Firestone Flexometer

|                    |      |      |      |
|--------------------|------|------|------|
| Running Temp., °F  | 226  | 240  | 275  |
| Deflection, %      | 15.3 | 16.7 | 20.7 |
| Shore "A" Hardness | 64   | 63   | 62   |

##### Ring Tear

|                    |     |     |     |
|--------------------|-----|-----|-----|
| Normal-70°F, lb/in | 800 | 500 | 525 |
| -212°F, lb/in      | 300 | 200 | 275 |

##### Brittle Point

|                   |     |     |     |
|-------------------|-----|-----|-----|
| ASTM D746-57T, °F | -63 | -60 | -45 |
|-------------------|-----|-----|-----|

#### 4. COMPOUND PROPERTIES

##### SIDEWALL

| Compound Line Up:           | I                         | II          | III          |
|-----------------------------|---------------------------|-------------|--------------|
| Tire Identification Serial: | K12500, K12700,<br>K12800 | K12600      | K12900       |
| Formulation:                | 50 NR                     | 50 NR       | 131 FR-S 123 |
|                             | 50 Neoprene               | 50 Isoprene |              |

##### Normal (70°F) Stress-Strain

|                   |      |      |      |
|-------------------|------|------|------|
| Tensile, psi      | 3175 | 3725 | 3000 |
| 300% Modulus, psi | 900  | 975  | 500  |
| Elongation, %     | 640  | 635  | 765  |

##### Tensile @ 275°F.

|               |     |     |     |
|---------------|-----|-----|-----|
| Tensile, psi  | 700 | 700 | 400 |
| Elongation, % | 350 | 360 | 270 |

##### Normal (70°F) Tensile After 2 Days @ 212°F

|               |      |      |      |
|---------------|------|------|------|
| Tensile, psi  | 1975 | 1025 | 2575 |
| Elongation, % | 405  | 265  | 570  |

##### Firestone Flexometer

|                    |      |      |      |
|--------------------|------|------|------|
| Running Temp., °F  | 203  | 201  | 246  |
| Deflection, %      | 26.7 | 20.0 | 24.7 |
| Shore "A" Hardness | 50   | 57   | 57   |

##### Ring Tear

|                    |     |     |     |
|--------------------|-----|-----|-----|
| Normal-70°F, lb/in | 325 | 575 | 400 |
| -212°F, lb/in      | 100 | 225 | 175 |

##### Brittle Point

|                   |     |     |     |
|-------------------|-----|-----|-----|
| ASTM D746-57T, °F | -71 | -53 | -45 |
|-------------------|-----|-----|-----|



#### 4. COMPOUND PROPERTIES

##### BODY

|                   |                   |                   |                   |                   |
|-------------------|-------------------|-------------------|-------------------|-------------------|
| Compound Line Up: | I                 | II                | III               | I,II,III          |
| Formulation:      | <u>Outer Body</u> | <u>Outer Body</u> | <u>Outer Body</u> | <u>Inner Body</u> |
|                   | 100 NR            | 100 NR            | 75 NR             | 75 NR             |
|                   |                   |                   | 25 Isoprene       | 25 Diene          |

##### Normal (70°F) Stress-Strain

|                   |      |      |      |      |
|-------------------|------|------|------|------|
| Tensile, psi      | 4125 | 4100 | 3975 | 2900 |
| 300% Modulus, psi | 1200 | 925  | 875  | 800  |
| Elongation, %     | 600  | 670  | 685  | 580  |

##### Tensile @ 275°F.

|               |      |      |      |     |
|---------------|------|------|------|-----|
| Tensile, psi  | 1250 | 1250 | 1025 | 475 |
| Elongation, % | 520  | 630  | 540  | 220 |

##### Normal (70°F) Tensile After 2 Days @ 212°F

|               |      |      |      |      |
|---------------|------|------|------|------|
| Tensile, psi  | 2050 | 1675 | 1925 | 1525 |
| Elongation, % | 375  | 390  | 425  | 405  |

##### Firestone Flexometer

|                    |      |      |      |      |
|--------------------|------|------|------|------|
| Running Temp., °F  | 189  | 184  | 188  | 132  |
| Deflection, %      | 23.3 | 24.7 | 26.0 | 20.7 |
| Shore "A" Hardness | 52   | 51   | 49   | 54   |

##### Ring Tear

|                    |     |     |     |     |
|--------------------|-----|-----|-----|-----|
| Normal-70°F, 1b/in | 550 | 850 | 550 | 200 |
| -212°F, 1b/in      | 300 | 350 | 325 | 125 |

##### Brittle Point

|                   |     |     |     |     |
|-------------------|-----|-----|-----|-----|
| ASTM D746-57T, °F | -69 | -67 | -63 | -66 |
|-------------------|-----|-----|-----|-----|

#### 4. COMPOUND PROPERTIES

##### REMAINDER OF COMPOUNDS

Innerliner, Bead Insulation, Bead Cover, Bead Filler, Chafer and Abrasion Gum Strip compounds are all standard Firestone compounds.

## 5. PROTECTION FROM ATMOSPHERIC DETERIORATION

### COMPOUND PROTECTION

Tread and sidewall compounds feature standard Firestone Off-The-Road antiozonants for maximum resistance to atmospheric deterioration.

The oil extended FR-S tread and sidewall, and the Neoprene/natural rubber sidewall are superior to the Standard Military Control for accelerated weathering in the Firestone Weatherometer.

The natural rubber and Isoprene treads, and the natural rubber/Isoprene sidewall, while somewhat inferior to the Standard Military Control for accelerated conditions, are expected to be well protected for normal operations.

Comparisons of tread and sidewall compounds and the Standard Military Control were made in the Firestone Weatherometer under the following conditions:

1. 60 parts per 100 million of Ozone - 40 hrs. exposure-static - 100°F. - pre-aged 3 days at 158°F - 12½% elongation
2. Same as above except dynamic (10 min. flex - 50 min. static per hour) and strips not pre-aged
3. Same as (1) above except exposure at 40°F.

Photographs of results are on the following pages.

FIRESTONE WEATHEROMETER  
60 PPHM OZONE, 40 HOURS, DYNAMIC, 100°F  
TREAD COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I  
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II  
TIRE SERIALS K12600

COMPOUND LINE UP III  
TIRE SERIALS K12900

FIRESTONE WEATHEROMETER -  
60 PPHM OZONE, 40 HOURS, STATIC, 100°F

AGED 3 DAYS AT 158°F

TREAD COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I  
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II  
TIRE SERIALS K12600

COMPOUND LINE UP III  
TIRE SERIALS K12900

FIRESTONE WEATHEROMETER  
60 PPHM OZONE, 40 HOURS, STATIC, 40°F  
AGED 3 DAYS AT 158°F  
TREAD COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I  
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II  
TIRE SERIALS K12600

COMPOUND LINE UP III  
TIRE SERIALS K12900

FIRESTONE WEATHEROMETER  
60 PPHM OZONE, 40 HOURS, DYNAMIC, 100°F  
SIDEWALL COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I  
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II  
TIRE SERIALS K12600

COMPOUND LINE UP III  
TIRE SERIALS K12900

FIRESTONE WEATHEROMETER  
60 PPHM OZONE, 40 HOURS, STATIC, 100°F

AGED 3 DAYS AT 158°F  
SIDEWALL COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I  
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II  
TIRE SERIALS K12600

COMPOUND LINE UP III  
TIRE SERIALS K12900



FIRESTONE WEATHEROMETER  
60 PPHM OZONE, 40 HOURS, STATIC, 40°F

AGED 3 DAYS AT 158°F  
SIDEWALL COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I  
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II  
TIRE SERIALS K12600

COMPOUND LINE UP III  
TIRE SERIALS K12900

## 6. PROTECTION FROM ATMOSPHERIC DETERIORATION

### PROTECTIVE COATINGS

From previous experience and studies during the period of this contract, the following two coatings were selected as the most practical.

- A. Firestone protective coating based on N, N'-dioctyl-p-phenylene diamine.
- B. Firestone protective coating based on Hypalon.

Coating A protects against atmospheric deterioration by depositing a layer of antiozonant which is absorbed into the surface of the tire.

Coating B protects against atmospheric deterioration by depositing a tough, clinging, elastic, protective film on the surface of the tire.

These coatings are very effective, but have the deficiency typical of coatings in that severe weathering occurs where the film is broken or not continuous, as shown in the photographs.

Comparisons of accelerated weathering, in the Firestone Weatherometer, of these coatings on the natural rubber tread (Line Up I), the Isoprene tread (Line Up II), and the natural rubber/Isoprene sidewall (Line Up II) are shown in the attached photographs.

Test conditions are the same as those described under Compound Protection.

FIRESTONE WEATHEROMETER  
60 PPHM OZONE, 40 HOURS, DYNAMIC 100°F  
TREAD COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I - COATING A  
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP I - COATING B  
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II - COATING A  
TIRE SERIALS K12600

COMPOUND LINE UP II - COATING B

FIRESTONE WEATHEROMETER  
60 PPHM OZONE, 40 HOURS, STATIC, 100°F

AGED 3 DAYS AT 158°F

TREAD COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I - COATING A  
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP I - COATING B  
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II - COATING A  
TIRE SERIALS K12600

COMPOUND LINE UP II - COATING B  
TIRE SERIALS K12600

FIRESTONE WEATHEROMETER  
60 PPHM OZONE, 40 HOURS, STATIC, 40°F  
AGED 3 DAYS AT 158°F  
TREAD COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I - COATING A  
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP I - COATING B  
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II - COATING A  
TIRE SERIALS K12600

COMPOUND LINE UP II - COATING B  
TIRE SERIALS K12600

FIRESTONE WEATHEROMETER  
60 PPHM OZONE, 40 HOURS, DYNAMIC, 100°F  
SIDEWALL COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP II - COATING A  
TIRE SERIALS K12600

COMPOUND LINE UP II - COATING B  
TIRE SERIALS K12600

FIRESTONE WEATHEROMETER  
60 PPHM OZONE, 40 HOURS, STATIC, 100°F

AGED 3 DAYS AT 158°F  
SIDEWALL COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP II - COATING A  
TIRE SERIALS K12600

COMPOUND LINE UP II - COATING B  
TIRE SERIALS K12600

FIRESTONE WEATHEROMETER  
60 PPHM OZONE, 40 HOURS, STATIC, 40°F  
AGED 3 DAYS AT 158°F  
SIDEWALL COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP II - COATING A  
TIRE SERIALS K12600

COMPOUND LINE UP II - COATING B  
TIRE SERIALS K12600



## B. DURABILITY TESTS

### 1. COMPOUND MODIFICATIONS

Prior to fabricating the 29.5-25, 16 ply SGG GOER tires for the Durability Tests, a review of the original three compound line ups' performance pointed out the need for some reconsiderations of the compound design. In order to improve the tires' durability characteristics from an overall compromise between cool running and cut, chip and wear resistance, a number of modifications were made in the compounding design. An overall compromise, utilizing the maximum synthetic content felt to be permissible, was chosen for one set of tires (K25500 Serial Identification), to be tested against control tires (K25300 Serial Identification) using standard Firestone Off-The-Road compounds (approximately all natural rubber).

The final selection of compounds featured a three-piece tread construction (details below) to obtain the best compromise between cool running for separation resistance and cut, chip, tear and wear resistance, while incorporating synthetic into a portion of tread.

The final compound combination resulted in a synthetic content of 50% of the polymer used.

Tread Cap or Veneer: An all-synthetic compound with a polymer blend of 50% Diene and 50% oil-extended FRS. The synthetic portion of the tread is confined to essentially only the lugs of the design to keep its higher heat build-up characteristics (relative to natural rubber) away from the critical separation area of the tire on top of the tire carcass. The use of Diene imparts added wear and cracking resistance over the previous all oil-extended FRS tread compound (original contract work, Compound Line Up III), plus giving an improvement in low temperature flexibility.

Tread Base: An intermediate layer of a compound with a 75% natural rubber-25% Isoprene polymer blend, compounded to provide the best compromise between cool running and wear, cut, chip and tear resistance. The use of a predominantly natural rubber compound between the tread cap and carcass permits the use of the all-synthetic tread cap with no loss in separation resistance.

Tread Cushion: A separation-resistant layer compound lying between the tread base and tire carcass. This compound contains a polymer blend of 75% natural rubber and 25% Isoprene and is compounded for the best cool running features with the minimum sacrifice in wear, cut, chip and tear resistance. This compound in combination with the tread cap and tread base constitute the three-piece tread construction for the best overall compromise of tire compound properties.

Outer Body: Same as Tread Cushion.

Inner Body: Compounded for cool running and heat resistance, the Inner Body features a polymer blend of 75% natural rubber and 25% Isoprene.

Innerliner: Compounded with a polymer blend of 58% chlorobutyl, 24% natural rubber, and 18% Diene, this Innerliner features improved low temperature flexibility (due addition of Diene), over previous compound used in original contract tires, in addition to properties mentioned previously.

Remainder of Compounds:

Sidewall - Firestone standard Military Truck tire compound.

Others - Firestone standard Off-The-Road compounds.

Coatings - Firestone Coating A referred to under original contract compounding.

## 2. COMPOUND PROPERTIES

|  | <u>TREAD<br/>CAP</u> | <u>TREAD<br/>BASE</u> | <u>TREAD<br/>CUSHION</u> | <u>INNER<br/>BODY</u> | <u>INNERLINER</u> |
|--|----------------------|-----------------------|--------------------------|-----------------------|-------------------|
| <u>Normal (70°F) Stress-Strain</u>                   |                      |                       |                          |                       |                   |
| Tensile, psi   | 2850                 | 3600                  | 3675                     | 3675                  | 1275              |
| 300% Modulus, psi                                    | 650                  | 1000                  | 725                      | 675                   | 600               |
| Elongation, %  | 710                  | 590                   | 645                      | 610                   | 560               |
| <u>Tensile @ 275°F</u>                               |                      |                       |                          |                       |                   |
| Tensile, psi   | 650                  | 825                   | 725                      | 525                   | -                 |
| Elongation, %  | 290                  | 425                   | 450                      | 495                   | -                 |
| <u>Normal (70°F) Tensile<br/>After *Days @ 212°F</u> |                      |                       |                          |                       |                   |
| Tensile, psi   | 2475                 | 1725                  | 1275                     | 1525                  | 1175              |
| Elongation, %  | 420                  | 370                   | 335                      | 410                   | 480               |
| <u>Firestone Flexometer</u>                          |                      |                       |                          |                       |                   |
| Running Temp., °F                                    | 288                  | 192                   | 184                      | 138                   | 236               |
| Deflection, %  | 18.7                 | 12.7                  | 26.0                     | 24.7                  | 24.7              |
| Shore "A" Hardness                                   | 64                   | 58                    | 52                       | 51                    | 53                |
| <u>Ring Tear</u>                                     |                      |                       |                          |                       |                   |
| Normal-70°F, lb/in                                   | 525                  | 300                   | 350                      | 575                   | -                 |
| -212°F. lb/in  | 300                  | 150                   | 150                      | 225                   | -                 |
| <u>Brittle Point</u>                                 |                      |                       |                          |                       |                   |
| ASTM D746-57T, °F.                                   | -78                  | -54                   | -56                      | -59                   | -60               |

\*Aging 6 days at 212°F. for Innerliner  
2 days at 212°F. for All Others

### 3. TEST RESULTS

#### GENERAL CONSIDERATIONS

In view of the satisfactory performance of the previously mentioned three-piece tread construction for durability and the synthetic tread cap for wear in the Durability Tests, it was decided to use this compounding construction on the 29.5-25 16 Ply Rating SGG GOER tire manufactured for European Troop Tests. However, due to the synthetic's inherent weakness for crack growth, which evidenced itself quite prominently during the Durability Tests, modification of the synthetic tread cap stock was necessary.

#### TREAD COMPOUND MODIFICATIONS

The synthetic tread cap compound was modified in line with other Firestone compounding practices and experience to improve the compound's crack initiation and growth resistance. These modifications reduced the compound's ability to meet the Standard Military Ozone requirements; however, it is felt that the compound's resistance to atmospheric deterioration, especially with the protective coating used, is adequate. In general the compound's properties are similar to those of the tread cap compound listed under Durability Tests. The improvement in crack initiation and crack growth can be seen from the following data:

#### Firestone Groove Flexing Machine

|                                      | <u>Previous<br/>Compound</u> | <u>Modified<br/>Compound</u> | <u>Per Cent<br/>Improvement</u> |
|--------------------------------------|------------------------------|------------------------------|---------------------------------|
| Crack Initiation<br>(Minutes to Crk) | 250                          | 510                          | 104                             |
| Crack Growth (Inches/<br>Hour)       | .258                         | .110                         | .174                            |

29.5-25 GOER TIRE DRUM TEMPERATURE  
COMPARISON

Equipment: 70.5" diameter steel drum powered by Allis Chalmers 100 H.P.  
AC Electric motor - 440 volts 495 RPM.

Brown Temperature Recorder and Copper-Constantan Thermocouples.

Test Features:

| <u>Serial</u> | <u>Features</u>                          |                    |
|---------------|--|--------------------|
|               | <u>Design</u>                            | <u>Compounding</u> |
| K12500        | Super Ground Grip Goer                   | 11% Synthetic      |
| K12600        | Super Ground Grip Goer                   | 52% Synthetic      |
| K12700        | Super Ground Grip Goer<br>(With Grooves) | 13% Synthetic      |
| K12800        | ND-CC Goer                               | 14% Synthetic      |
| K12900        | ND-CC Goer                               | 56% Synthetic      |

Test Conditions:

Load - 18,500 flat plate load  
Speed - 17.1 MPH  
Inflation - 40 psi  
Ambient Temperature - 68°F

Test Results:

| <u>Serial</u> | <u>Tread Temperature</u> |                  |                           | <u>Contained Miles<br/>Air Temp.</u> | <u>Run</u> | <u>Final Hot<br/>Inflation</u> |
|---------------|--------------------------|------------------|---------------------------|--------------------------------------|------------|--------------------------------|
|               | <u>Center</u>            | <u>Mid Point</u> | <u>Shoulder(Hot Spot)</u> |                                      |            |                                |
| K12500-2      | 179                      | 197              | 208                       | 144                                  | 150        | 48                             |
| K12600-1      | 201                      | 221              | 229                       | 149                                  | 150        | 50                             |
| K12700-4      | 177                      | 191              | 196                       | 145                                  | 150        | 49                             |
| K12800-2      | 196                      | 206              | 222                       | 147                                  | 150        | 50                             |
| K12900-2      | 227                      | 230              | 240                       | 142                                  | 113        | 47                             |

Conclusions:

1. Using the Super Ground Grip Goer as a control (K12500) for a running temperature comparison of these three designs, we see that the Super Ground Grip Goer (with grooves) is 12° cooler running and the ND-CC Goer is 14° hotter running than this control.

2. There are two comparisons of the effect of synthetic content on running temperature:

A. K12500 (11%) vs. K12600 (52%)  
(208°) (229°) +21°

B. K12800 (14%) vs. K12900 (56%)  
(222°) (240°) +18°

This shows that the higher synthetic content is 18-21° hotter than the same tire with the lower synthetic content.

NOTE: These drum temperatures can not be construed as indicative of actual operating temperatures under these same conditions. Only a comparison of one vs. another can be made.

29.5-25 GOER TIRE  
ON-VEHICLE TEMPERATURE COMPARISON  
CONTINUOUS HIGHWAY SERVICE

Discussion

These on-vehicle temperature tests provide a comparison of the three designs (Super Ground Grip Goer, Super Ground Grip Goer with grooves, and ND-CC Goer) and also a comparison of high synthetic content (52 - 56%) vs. low synthetic content (11 - 14%).

All tires were tested on the same XM438 Goer Tanker with a gross vehicle weight of 69,800 lbs.

All tests were conducted on a 3-1/8 mile loop of highway which was part of the A.A.S.H.O. road test at Ottawa, Illinois. The duration of each test run was determined by the equilibrium point. When the temperatures leveled off, the tests were terminated. The tests were conducted 11-15, September 1961.

Test Features:

| <u>Serial</u> | <u>Features</u>                          |                    |
|---------------|--|--------------------|
|               | <u>Design</u>                            | <u>Compounding</u> |
| K12500        | Super Ground Grip Goer                   | 11% Synthetic      |
| K12600        | Super Ground Grip Goer                   | 52% Synthetic      |
| K12700        | Super Ground Grip Goer<br>(With Grooves) | 13% Synthetic      |
| K12800        | ND-CC Goer                               | 14% Synthetic      |
| K12900        | ND-CC Goer                               | 56% Synthetic      |

Test Conditions:

|           |                            |
|-----------|----------------------------|
| Load      | 69,800 lbs. G.V.W.         |
| Inflation | 40 psi drive, 30 psi trail |
| Speed     | 29 MPH Average.            |

Test Results (All Temperatures Corrected to 68° Ambient)

Inflation Actual Maximum

| <u>Type</u>                              | <u>Serial</u> | <u>Position</u> | <u>Cold</u> | <u>Hot</u> | <u>Ambient</u> | <u>Temp. (Corr.)</u> | <u>Hours Run</u> |
|--|---------------|-----------------|-------------|------------|----------------|----------------------|------------------|
| Super Ground Grip Goer                   | K12500-1      | RF              | 40          | 52         | 65°            | 241°                 | 4.7              |
| Super Ground Grip Goer                   | K12600-1      | LF              | 40          | 51         | 65°            | 272°                 | 4.7              |
| Super Ground Grip Goer                   | K12500-2      | LR              | 30          | 40         | 65°            | 234°                 | 4.7              |
| Super Ground Grip Goer                   | K12600-2      | RR              | 30          | 40         | 65°            | 239°                 | 4.7              |
| Super Ground Grip Goer<br>(With Grooves) | K12700-2      | RF              | 40          | 51         | 62°            | 217°                 | 5.7              |
| Super Ground Grip Goer<br>(With Grooves) | K12700-1      | LF              | 40          | 50         | 62°            | 219°                 | 5.7              |
| Super Ground Grip Goer<br>(With Grooves) | K12700-3      | LR              | 30          | 41         | 62°            | 213°                 | 5.7              |
| Super Ground Grip Goer<br>(With Grooves) | K12700-4      | RR              | 30          | 41         | 62°            | 206°                 | 5.7              |
| ND-CC Goer                               | K12800-1      | RF              | 40          | 54         | 63°            | 233°                 | 4.5              |
| ND-CC Goer                               | K12900-1      | LF              | 40          | 54         | 63°            | 255°                 | 4.5              |
| ND-CC Goer                               | K12800-2      | LR              | 30          | 43         | 63°            | 208°                 | 4.5              |
| ND-CC Goer                               | K12900-2      | RR              | 30          | 43         | 63°            | 236°                 | 4.5              |

Conclusions

1. The effect of design on running temperature can be readily determined since one tire of each design was run under the same conditions using the Super Ground Grip Goer (K12500) as a control:

| <u>Type</u>             | <u>Serial</u> | <u>Position</u> | <u>Maximum Temperature</u> |      |
|-------------------------|---------------|-----------------|----------------------------|------|
| SGG Goer                | K12500-1      | RF              | 241°                       | Par  |
| SGG Goer (With Grooves) | K12700-2      | RF              | 217°                       | -24° |
| ND-CC Goer              | K12800-1      | RF              | 233°                       | - 8° |
| SGG Goer                | K12500-2      | LR              | 234°                       | Par  |
| SGG Goer (With Grooves) | K12700-3      | LR              | 213°                       | -21° |
| ND-CC Goer              | K12800-2      | LR              | 208°                       | -26° |

These differences might be attributed to variations in the individual tires such as base gauge, etc.



2. The effect of synthetic content on tire operating temperature can also be determined. Four direct comparisons are available.

| <u>Serial</u> | <u>% Synthetic</u> | <u>Position</u> | <u>Maximum Temperature</u> |       |
|---------------|--------------------|-----------------|----------------------------|-------|
| K12500-1      | 11%                | RF              | 241°                       | +31°  |
| K12600-1      | 52%                | LF              | 272°                       |       |
| K12500-2      | 11%                | LR              | 234°                       | + 5°  |
| K12600-2      | 52%                | RR              | 239°                       |       |
| K12800-1      | 14%                | RF              | 233°                       | +22°. |
| K12900-1      | 56%                | LF              | 255°                       |       |
| K12800-2      | 14%                | LR              | 208°                       | +28°  |
| K12900-2      | 56%                | RR              | 236°                       |       |

Ave. Difference +22°

3. These tests determined that at inflation of 40 psi, drive and 30 psi, trail, the Super Ground Grip Goer tires (with grooves - K12700) should operate safely in continuous service at speeds under 30 MPH and at an ambient temperature of 68°.

We use 250°F as a critical temperature, and as an ambient temperature correction factor, we use 1/2°F tire temperature change for each 1°F. ambient change. It can be seen from these temperatures that at higher ambient temperatures all of the other designs would be marginal. Since it is desirable to use as high a synthetic content as possible, the Super Ground Grip Goer tire (with grooves) is the only one capable of continuous highway operation at high ambient temperatures when produced with the high synthetic construction.

## TRACTION TEST SUMMARY

### SAND, COMPRESSIBLE SOIL, AND NON-COMPRESSIBLE SURFACE

Discussion: The data and resulting conclusions shown in this summary have been abstracted from:

Final Report  
Phase I  
Project 20-1-102

Traction Ability of Various 29.5-25 Goer Tires in Sand, in a Compressible Soil, and on a Non-Compressible Surface.

This report was prepared by Nevada Automotive Test Center, Carson City, Nevada for Le-Tourneau Westinghouse Company in September, 1962.

### OBJECT

The object of this test program was to evaluate the tractive ability of the following test tire groups (each featuring a difference in tread design) in sand, in compressible soil and on non-compressible surface.

- Group A: Firestone Ground Grip (Control Tires),  
16 PR Directional Design, 29.5-25.  
Serial numbers K-4300-9 and K-4300-14.
- Group B: Firestone ND-CC Goer, 16 PR  
29.5-25.  
Serial numbers K-12900-2 and K-12900-1.
- Group C: Firestone Super Ground Grip Goer, 16 PR,  
Grooved Lug, 29.5-25.  
Serial numbers K-21700-4 and K-12700-3.
- Group D: Firestone Super Ground Grip Goer, 16 PR,  
Solid Lug, 29.5-25.  
Serial numbers K12500-1 and K-12600-1.

## CONCLUSIONS

### SAND

In prepared sand simulating the loose "blow" sand common to the lee side of beach and desert dunes the initial desirable inflation pressure increments of 40, 30 and 20 PSI were predictably high for vehicle operation in the type of sand available at the test site. 20 PSI was found to be the maximum test pressure to which the tires could be inflated to permit movement of the test vehicle from highway to the sand course over a sand road traversable by jeep and pickup.

With maximum sand tire inflation pressure established at 20 PSI, 16 and 12 PSI were arbitrarily selected as the lower increments at which data would be generated.

Little significant difference in performance existed between these tires at 20, 16 and 12 PSI.

The 12 PSI inflation pressure would not be practical for any of these tires due to the severe traction buckle which appeared at this low pressure. Two of the eight tires tested experienced slippage between tire and rim.

The sand gradeability of the 64,000 lb. Goer vehicle equipped with Conventionally designed tires on all four drive wheels is calculated to be as follows:

| Tire Group<br>Inflation, Press.                               | A   |     |     | B  |     |     | C   |     |     | D   |     |     |
|---|-----|-----|-----|----|-----|-----|-----|-----|-----|-----|-----|-----|
|   | 20  | 16  | 12  | 20 | 16  | 12  | 20  | 16  | 12  | 20  | 16  | 12  |
| Gradeability, %   | 25  | 30  | 34  | 24 | 29  | 34  | (1) | 29  | 32  | 27  | 29  | 32  |
| Gradeability<br>Rating as compared<br>with Control<br>Group A | 100 | 100 | 100 | 96 | 97  | 100 | (1) | 97  | 94  | 108 | 97  | 94  |
| Travel Efficiency<br>Rating as compared<br>with Control       | 100 | 100 | 100 | 95 | 103 | 96  | (1) | 103 | 101 | 100 | 104 | 103 |

(1) Could not negotiate sand course with drawbar load.

### COMPRESSIBLE SOIL WITH GROUND COVER

As opposed to sand, tires in compressible soil continue to develop progressively more drawbar as travel efficiency diminishes (increased wheel spin). This being the case, comparative performance in terms of drawbar must be judged at comparable travel efficiency points. For specific comparisons see SUMMARY OF TEST RESULTS, Tractive Ability, Compressible Soil with Ground Cover. Of the experimental tires, the ND-CC Goer design, Group B, provided maximum drawbar pull under these conditions.

CONCLUSIONS (CONTINUED)

NON-COMPRESSIBLE SURFACE

Under these conditions, the Super Ground Grip Goer, Group D, provided the maximum drawbar pull of any of the experimental designs.

Tractive Ability: Sand[illegible]

## SUMMARY OF TEST RESULTS

### Tractive Ability, Compressible Soil with Ground Cover

|  | % T.E.                      | 40 PSI       |              |              | 30 PSI       |              |              | 20 PSI       |              |              |
|--|-----------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
|  |                             | 90           | 75           | 60           | 90           | 75           | 60           | 90           | 75           | 60           |
| A<br>Firestone Ground<br>Grip WB (Control Tires)<br>16 PR      | Drawbar<br>Rating           | 9000<br>100  | 16200<br>100 | 19300<br>100 | 10800<br>100 | 16600<br>100 | 18700<br>100 | 11300<br>100 | 16300<br>100 | 18400<br>100 |
|  | Est. Grade.<br>(4 Wh. Dr.)  | 26           | 48           | 57           | 32           | 49           | 55           | 33           | 48           | 54           |
|  | Calc. Grade.<br>(2 Wh. Dr.) | 14           | 25           | 30           | 17           | 26           | 29           | 18           | 25           | 29           |
| B<br>Firestone NDCC Goer<br>Mil. 16 PR                         | Drawbar<br>Rating           | 11100<br>123 | 18000<br>111 | 19900<br>103 | 11600<br>107 | 17600<br>106 | 19700<br>105 | 9200<br>81   | 15700<br>96  | 18800<br>102 |
|  | Est. Grade.<br>(4 Wh. Dr.)  | 33           | 53           | 59           | 34           | 52           | 58           | 27           | 46           | 55           |
|  | Calc. Grade.<br>(2 Wh. Dr.) | 17           | 28           | 31           | 18           | 27           | 31           | 14           | 25           | 29           |
| F<br>Firestone Super Ground<br>Grip Goer, 16 PR<br>Grooved Lug | Drawbar<br>Rating           | 9200<br>102  | 14800<br>91  | 18200<br>94  | 8300<br>77   | 14000<br>84  | 17900<br>96  | 8700<br>77   | 14500<br>89  | 18100<br>98  |
|  | Est. Grade.<br>(4 Wh. Dr.)  | 27           | 44           | 54           | 24           | 41           | 53           | 26           | 43           | 53           |
|  | Calc. Grade.<br>(2 Wh. Dr.) | 14           | 23           | 28           | 13           | 22           | 28           | 14           | 23           | 28           |
| G<br>Firestone Super Ground<br>Grip Goer, 16 PR<br>Solid Lug   | Drawbar<br>Rating           | 10600<br>117 | 15800<br>98  | 18200<br>94  | 9700<br>90   | 15700<br>95  | 18100<br>97  | 8000<br>71   | 15500<br>95  | 18000<br>98  |
|  | Est. Grade.<br>(4 Wh. Dr.)  | 31           | 46           | 54           | 29           | 46           | 53           | 24           | 46           | 53           |
|  | Calc. Grade.<br>(2 Wh. Dr.) | 17           | 25           | 28           | 15           | 24           | 28           | 12           | 24           | 28           |

SUMMARY OF TEST RESULTS (Continued)

| <u>Tractive Ability, Compressible Soil with Ground Cover</u>                                |          |          |          |          |
|---|----------|----------|----------|----------|
| <u>Averaged Drawbar Values (at 90, 75 and 60% Travel Efficiency) Rated Against Group A.</u> |          |          |          |          |
| <u>Group</u>  | <u>A</u> | <u>B</u> | <u>C</u> | <u>D</u> |
| Infl. Press., 40 PSI  | 14800    | 16300    | 14100    | 14900    |
| Rating  | 100      | 110      | 95       | 101      |
| 30 PSI  | 15400    | 16300    | 13400    | 14500    |
| Rating  | 100      | 106      | 87       | 94       |
| 20 PSI  | 15300    | 14600    | 13800    | 13800    |
| Rating  | 100      | 95       | 90       | 90       |

# SUMMARY OF TEST RESULTS (Continued)

## Tractive Ability, Non-Compressible Surface (Continued)

|  | % T.E.                      | 40 PSI |       |       | 30 PSI |       |       | 20 PSI |       |       |
|--|-----------------------------|--------|-------|-------|--------|-------|-------|--------|-------|-------|
|  |                             | 90     | 75    | 60    | 90     | 75    | 60    | 90     | 75    | 60    |
| A  |                             |        |       |       |        |       |       |        |       |       |
| Firestone Ground Grip WB<br>(Control Tires) 16 PR        | Drawbar                     | 18000  | 21300 | 21900 | 16500  | 21200 | 21700 | 7800   | 19000 | 20400 |
|  | Rating                      | 100    | 100   | 100   | 100    | 100   | 100   | 100    | 100   | 100   |
|  | Est. Grade.<br>(4 Wh. Dr.)  | 53     | 63    | 64    | 49     | 62    | 64    | 23     | 56    | 60    |
|  | Calc. Grade<br>(2 Wh. Dr.)  | 28     | 33    | 34    | 26     | 33    | 34    | 12     | 30    | 32    |
| B  |                             |        |       |       |        |       |       |        |       |       |
| Firestone NDCC Goer<br>16 PR                             | Drawbar                     | 12700  | 22100 | 24300 | 7700   | 17400 | 23200 | 8400   | 18700 | 22400 |
|  | Rating                      | 71     | 104   | 110   | 47     | 82    | 107   | 107    | 98    | 110   |
|  | Est. Grade.<br>(4 Wh. Dr.)  | 37     | 65    | 71    | 23     | 51    | 68    | 25     | 55    | 66    |
|  | Calc. Grade.<br>(2 Wh. Dr.) | 20     | 35    | 38    | 12     | 27    | 36    | 13     | 29    | 35    |
| C  |                             |        |       |       |        |       |       |        |       |       |
| Firestone Super Ground Grip Goer<br>16 PR, Grooved Lug   | Drawbar                     | 9300   | 19100 | 24300 | 7500   | 15900 | 22900 | 7500   | 16300 | 21900 |
|  | Rating                      | 52     | 90    | 110   | 45     | 75    | 106   | 96     | 86    | 107   |
|  | Est. Grade.<br>(4 Wh. Dr.)  | 27     | 56    | 71    | 22     | 47    | 67    | 22     | 48    | 62    |
|  | Calc. Grade.<br>(2 Wh. Dr.) | 15     | 30    | 38    | 12     | 25    | 36    | 12     | 25    | 34    |
| D  |                             |        |       |       |        |       |       |        |       |       |
| Firestone Super Ground<br>Grip Goer, 16 PR,<br>Solid Lug | Drawbar                     | 14400  | 20600 | 21500 | 14300  | 20900 | 22100 | 14300  | 20600 | 21800 |
|  | Rating                      | 80     | 97    | 98    | 87     | 99    | 102   | 183    | 108   | 107   |
|  | Est. Grade.<br>(4 Wh. Dr.)  | 42     | 61    | 63    | 42     | 61    | 65    | 42     | 61    | 64    |
|  | Calc. Grade.<br>(2 Wh. Dr.) | 23     | 32    | 34    | 23     | 33    | 35    | 23     | 32    | 34    |



SUMMARY OF TEST RESULTS (Continued)

Tractive Ability, Non-Compressible Surface

Averaged Drawbar Values (at 90, 75 and 60% Travel Efficiency)  
Rated Against Group A.

| <u>Group</u>         | <u>A</u> | <u>B</u> | <u>C</u> | <u>D</u> |
|----------------------|----------|----------|----------|----------|
| Infl. Press., 40 PSI | 20400    | 19700    | 17600    | 18800    |
| Rating               | 100      | 97       | 86       | 92       |
| 30 PSI               | 19800    | 16100    | 15400    | 19100    |
| Rating               | 100      | 81       | 78       | 96       |
| 20 PSI               | 15700    | 16500    | 15200    | 18900    |
| Rating               | 100      | 105      | 97       | 120      |

FINAL REPORT

DURABILITY TEST OF GOER TIRES  
Phase III

Project 20-1-110

July 1963

Prepared For  
LeTourneau-Westinghouse Company  
Under Test Directive 224 Revised

Prepared By:

*Walter H. Statton*

Walter H. Statton  
Vice President

Approved By:

*Henry C. Hodges*

Henry C. Hodges  
President

Nevada Automotive Test Center  
Carson City, Nevada

A Division of Hodges Transportation Inc.

FINAL REPORT

Project 20-1-110

Upper Photograph

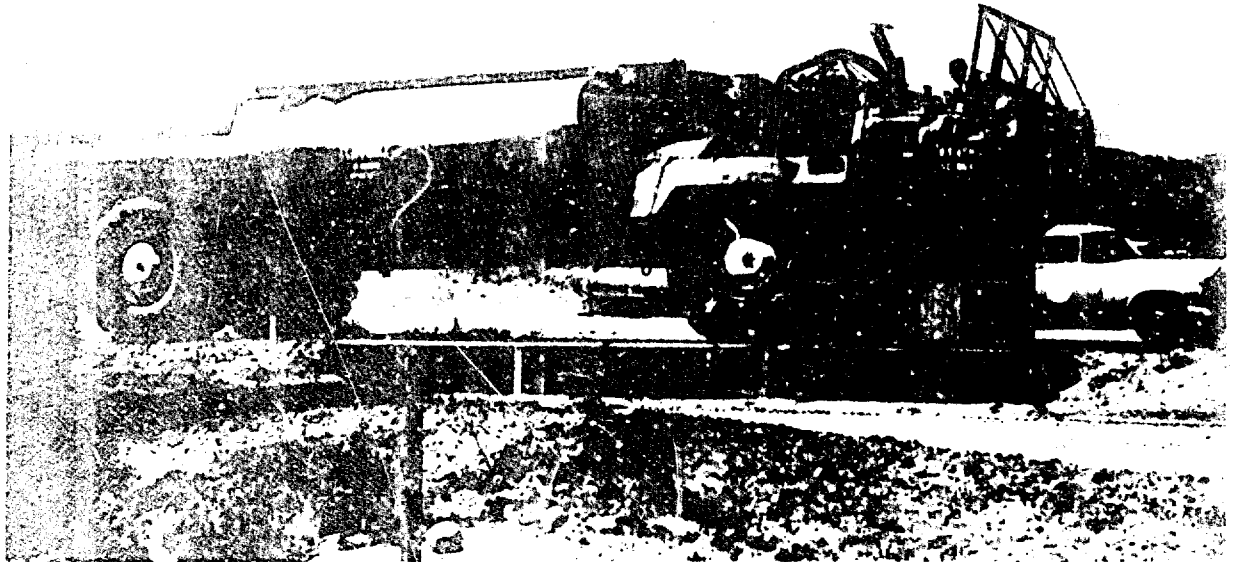
X1 43822 Fuel Tank Truck being Weighed Prior  
to "Ride" Evaluation

Lower Photograph

Three (3) Commercial Model "C" Tournapull  
Vehicles Used In Tread Wear and Durability Test

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# FINAL REPORT

Project 20-1-110

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HISTORY

In August 1962 the Nevada Automotive Test Center, A Division of Hodges Transportation Inc., conducted an Engineering Study (Project 20-1-102) of the influence of tire tread design and carcass construction on the tractive efficiency of 29.5 - 25 tires applicable to unsprung four wheel vehicles such as the Model "C" Tourmapull and the ATAC "Goer".

In February 1963 two experimental tire groups and one control (Standard "Goer" 29.5 - 25) tire group were applied to three commercial Model "C" Tourmapull "test bed" vehicles for the purpose of establishing the comparative durability and tread wear performance of these tires when subjected to semi-continuous operation over paved highways, "washboard" secondary roads and cross-country trails.

OBJECT

The three tire test groups selected for this durability and tread wear study featured significant differences and the test program was set up to segregate the effect of these differences in terms of tire durability and tread wear:

Tire Group A, the standard 29.5 - 25 directional tread "Goer" tires, featured 16 ply conventional construction and natural rubber tread.

Tire Group B, the experimental 29.5 - 25 non-directional tread tires, featured radial ply construction.

Tire Group C, the experimental 29.5 - 25 directional tread tires, featured 16 ply conventional construction and synthetic rubber tread.

Two additional tire groups were available for durability and tread wear testing (Groups D and E) should premature failures develop in the original test tire groups.

Tire Group D, the experimental 29.5 - 25 non-directional tread tires, featured 16 ply conventional construction.

Tire Group E, the experimental 29.5 - 25 directional tread tires, featured radial ply construction.

One additional group of non-directional radial ply construction tires (Group F) with the same features as Group B was available for engineering investigation.

## TEST PLAN

The tread wear and durability test plan established a requirement for the following:

A maximum of 20,000 vehicle miles per tire test group divided into 8,000 miles of pavement operation, 8,000 miles of secondary road operation and 4,000 miles of cross-country trail operation.

Front tire loads of approximately 19,400 lbs. per tire and rear tire loads of 16,000 lbs. per tire simulating the tire loads of the ATAC "Goer" fuel tank truck, XM 438E2.

Measurements of tread wear and tire deterioration each 2,500 miles of operation.

Rotation of test tires from vehicle to vehicle each measurement period to equate vehicle "test bed" differences.

Test speeds averaging 25 MPH on pavement, 25 MPH on secondary roads and 8 MPH over cross-country trails to be maintained commensurate with driver and vehicle safety.

Tire inflation at the maximum level permitted by cross-country terrain conditions in terms of driver and vehicle fatigue limits at the minimum average speed requirement of 8 MPH.

Tire temperatures on the pavement course.

Driver observations of vehicle "ride" and performance as influenced by tire reaction.

The specific test plan and procedures are set forth in detail in TEST PROGRAM of this report.



## CONCLUSIONS

The following conclusions may be drawn from the data generated under the specific conditions of this test program as summarized in TEST RESULTS.

### Tire Tread Wear

Regardless of tread design, tires of radial ply construction (Groups B and E) provide a significantly lower tread wear rate than tires of conventional construction (Groups A, C and D). Group B was 14% worn compared with A-79%, C-35% and D-32% worn at equal mileage.

With like tire construction, non-directional tread tires (Groups B and D) provide a lower tread wear rate than directional tread tires (Groups A, C and E).

The synthetic directional tread conventional construction tires (Group C) provide a significantly lower tread wear rate than the natural rubber directional tread conventional construction tires (Group A).

On the Model "C" Tournapull "test beds" rear tire wear rate exceeded front tire wear rate; however, in terms of irregular wear the non-directional design is not sensitive to axle position, whereas the directional design is sensitive.

Directional tread conventional construction tires (Group A) exhibit almost 100% higher lug pressure on the ground than do the non-directional tread radial ply tires (Group B) which increases unit rate of wear.

### Tire Durability

The synthetic directional tread conventional construction tires (Group C) developed substantially greater tread cracking than the natural rubber tread tires (Group A) of the same construction.

Conventional construction tires (Groups A and C) are significantly more durable than the radial ply construction tires (Group B) experiencing no carcass failures of the original eight test samples, whereas the radial ply construction experienced three carcass failures and one tread separation of the original four test samples and one carcass failure of the three replacement tires subjected to test.

The relative durability of the two additional tire groups cannot be assessed as the accumulated test miles authorized for a tread wear comparison of these groups (Groups D and E) were respectively 7,500 and 2,500 miles which were not adequate for durability comparison.

## CONCLUSIONS (Contd.)

### Tire Temperatures

The non-directional radial ply tires (Group B) under normal conditions of pavement test operation ran at a slightly lower mean temperature (198°F) than the Groups A and C directional conventional tires (202°F).

The non-directional conventional tires (Group D) under normal conditions of pavement test operation ran significantly cooler (210°F) than the Group E directional radial ply tires (237°F); however, while the operating conditions were equivalent during the time these temperatures were recorded the accumulated group tire mileages were not (Group D-7,500 miles, Group E-2,500 miles).

In the pavement operation established for this test (8 hours continuous) tire Groups A, B, C and D will not generate temperatures in excess of 235°F providing all tires are normal, i.e., no separations or traumatic frictional generators.

### Rolling Resistance

The directional conventional tires (Groups A and C) and the non-directional radial ply tires (Group B) were analyzed in terms of their relative influence on vehicle fuel consumption. A comparison of the fuel consumed by the three test vehicles applied to each tire group for an equal number of miles represents a rate of fuel consumption chargeable to each tire group without regard for vehicle differences. The foregoing disregards many possible variables but a trend was established from these data which showed a 6% improvement in the rate of fuel consumption attributable to the non-directional radial ply tires (Group B) when compared with the directional conventional tires (Group A) and an 8% improvement when compared with the directional conventional tires (Group C).

## CONCLUSIONS (Contd.)

### Instrumented "Ride" Study

Compared with the Model "C" Tournapull, the "Goer" Tanker at rated load provides significantly better "ride" characteristics on rough pavement and secondary road surfaces regardless of the influence of the tires.

In cross-country over natural obstacles the vehicle reaction is sharply sensitive to tire reaction which permits the equating of vehicle differences by tire selection, i.e., the "Goer" equipped with radial ply tires (Group F) is equally as acceptable as the Model "C" Tournapull equipped with conventional directional tires (Group A), whereas when these tires are reversed in vehicle assignment the two vehicles are equally "ride" deficient.

On pavement and secondary road surfaces the "ride" of the "Goer" Tanker equipped with non-directional radial ply tires (Group F) is essentially insensitive to limited tire pressure change, whereas the Model "C" Tournapull "ride" is extremely sensitive. Equipped with conventional directional tires (Group A) both vehicles exhibit a slight pressure change sensitivity.

By comparison the "ride" characteristics of the non-directional conventional tires (Group D) are considered deficient in any "rough" area on any surface when mounted on the Model "C" Tournapull. The non-directional radial ply tires (Group E) provide the best over-all Model "C" Tournapull "ride" on pavement and secondary road surfaces and better cross-country "ride" than the non-directional radial ply (Group F). Assuming the influence of the "Goer" on the cross-country "ride" of the Group F tires would hold true for the directional radial ply Group E tires, the Group E tires would provide a significantly better over-all "Goer" "ride" than any other tire group tested.

Using the Model "C" Tournapull as a "test bed" and under the eleven different test conditions in the "Ride" Study to which all tire groups were subjected the directional conventional (Group A) tires exceeded the human fatigue limit<sup>(1)</sup> under five conditions and the vehicle fatigue limit<sup>(2)</sup> under two conditions; the non-directional radial ply tires (Group F) exceeded the human fatigue limit under six conditions and the vehicle fatigue limit under three conditions; on the same comparative basis, the non-directional conventional ply tires (Group D) exceeded the human fatigue limit seven times and vehicle fatigue limit four times; and the directional radial ply tires (Group E) exceeded the human fatigue limit four times and the vehicle fatigue limit three times.

- (1) Acceptable "Human" Continuous Fatigue Limit of .89 (Ride Index), as Interpreted from Goldman's "Unpleasant" Limit.
- (2) Acceptable Vehicle Continuous Fatigue Limit of 1.91 (Ride Index), as Interpreted from Goldman's "Intolerable" Limit.

## CONCLUSIONS (Contd.)

### Instrumented "Ride" Study (Contd.)

Using the "Goer" Tanker as a "test bed" and under the same conditions applied to the Model "C" Tournapull "test bed" the directional conventional (Group A) tires exceeded the human fatigue limit three times and the vehicle fatigue limit once, whereas the non-directional radial ply (Group F) tires exceeded the human and vehicle fatigue limit only once under the single cross-country condition.

### Instrumented Shallow Mud Traction Study

Only the directional conventional (Group A) tires and the non-directional radial ply (Group F) tires were subjected to this Mud Traction Study and the following conclusions may be drawn from their performance.

The directional conventional (Group A) tires depend upon increased ground pressure for increased traction, whereas the non-directional radial ply (Group F) tires depend upon decreased ground pressure for increased traction.

At their optimum inflation pressure within the range investigated (15-55 psig) the maximum traction of the two groups being compared were equal at 55 psig for the Group A tires and 15 psig for the Group F tires.

The pressure print profile of the two groups at their maximum traction indicated a single high pressure contact in the crown of the Group A tires and two high pressure contacts at the shoulders of the Group F tires.

At their maximum traction the static lug ground pressure of the Group A tires is 228 PSI and the Group F tires is 48 PSI which influences tire flotation characteristics.

The vehicle ground clearance is reduced by the inflation pressure reduction required by the Group F tires.

In shallow mud the tread void areas of the Group A tires are cleared of mud buildup at 15 psig inflation, whereas the Group A are substantially loaded. At 55 psig inflation the Group A tread void areas are cleared of mud buildup and the Group F tires are substantially loaded.

## CONCLUSIONS (Contd.)

### Instrumented Shallow Mud Traction Study (Contd.)

#### CONSIDERATIONS FOR IMPROVING "GOER" MUD TRACTION

To achieve acceptable mobility, the "Goer" vehicle equipped with non-directional radial ply tires should not be operated in shallow mud with more than 25 psig front tire inflation pressure and 20 psig rear tire inflation pressure, whereas the directional conventional (Group A) tires should not be operated with less than 45 psig front tire inflation pressure and 40 psig rear tire inflation pressure.

To achieve acceptable soil trafficability (mud track pass factor) neither Group A nor Group F should be inflated to more than 25 psig.

These data indicate that in deep mud the directional tread (Group A) tires at 35, 45 or 55 psig inflation can negotiate a more severe condition in forward travel than in reverse; consequently, consideration should be given to what inflation pressure might be used to extricate the vehicle when forward travel is no longer possible.

Serious consideration should be given to evaluating the deep mud potential of:

1. Non-directional conventional and radial ply tires.
2. Directional conventional and radial ply tires.

## TEST RESULTS

Table I summarizes the results of the Tire Durability Test in terms of test miles to removal and tread wear rate.

TABLE I

|  | Tire Groups    |                  |                |                    |                    |
|--|----------------|------------------|----------------|--------------------|--------------------|
|  | A              | B                | C              | D                  | E                  |
| Average Test Miles<br>Per Tire Sample <sup>(1)</sup> | 10,022         | 8,604            | 15,040         | 7,509              | 2,541              |
| Reason for Removal                                   | Worn<br>Smooth | Radial<br>Cracks | Worn<br>Smooth | Test<br>Terminated | Test<br>Terminated |
| Durability Rating, %                                 | 100            | 86               | 150            | --                 | --                 |
| Tread Wear, Average<br>Miles/Mil <sup>(2)</sup>      | 6.1            | 29.9             | 12.2           | 16.3               | 20.3               |
| Tread Wear Rating, %                                 | 100            | 490              | 200            | 267                | 333                |

(1) The sum of the failed tire mileages divided by the number of failed tires equals average test miles per tire sample.

(2) These averages are based on two measurement locations (shoulder) and do not include crown wear. (See Summary of Tire Tread Wear; Final, By Period.)

TEST RESULTS (Contd.)

Table II summarizes the result of the "Ride" Study comparing tire group performance in terms of vehicle "ride" index values (See Appendix A, "Ride" Study). A "ride" index value of 0.89 is defined as being the acceptable limit of human fatigue for continuous operation.

TABLE II

| Condition           | Tire Groups |              |              |              |              |              |              |              |
|---------------------|-------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
|                     | A           |              | F            |              | D            |              | E            |              |
| Front Tire psig     | 40          | 50           | 40           | 50           | 40           | 50           | 40           | 50           |
| Rear Tire psig      | <u>30</u>   | <u>40</u>    | <u>30</u>    | <u>40</u>    | <u>30</u>    | <u>40</u>    | <u>30</u>    | <u>40</u>    |
| <u>"Ride" Index</u> |             |              |              |              |              |              |              |              |
| Pavement            |             |              |              |              |              |              |              |              |
| #1, Smooth          | 0.35        | 0.68         | 0.51         | 0.50         | 0.60         | 0.30         | 0.50         | 0.31         |
| #2, Rough           | <u>1.10</u> | <u>1.10</u>  | <u>2.30*</u> | 0.80         | <u>4.60*</u> | <u>2.00*</u> | <u>2.15*</u> | 0.72         |
| Secondary           |             |              |              |              |              |              |              |              |
| #1, Smooth          | 0.54        | 0.65         | 0.50         | <u>1.20</u>  | 0.44         | <u>0.98</u>  | 0.22         | 0.54         |
| #2, Smooth          | 0.52        | <u>1.21</u>  | 0.37         | <u>1.40</u>  | 0.24         | <u>1.90</u>  | 0.28         | <u>1.40</u>  |
| #3, Rough           | 0.85        | <u>2.38*</u> | <u>0.92</u>  | <u>2.90*</u> | <u>0.91</u>  | <u>4.30*</u> | 0.75         | <u>2.00*</u> |
| Cross-Country       |             |              |              |              |              |              |              |              |
| Rough               | <u>2.7*</u> | --           | <u>6.2*</u>  | --           | <u>10.2*</u> | --           | <u>5.4*</u>  | --           |

Underlined values are in excess of acceptable human fatigue limits for continuous operation.

(\*) Asterisked values are in excess of acceptable human and vehicle fatigue limits for continuous operation.

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TEST RESULTS (Contd.)

Table III summarizes the result of the "Ride" Study comparing the performance of the Model "C" Tournapull with the "Coer" Tanker, in terms of vehicle "Ride" index value (see Appendix A, Ride Study). A "ride" index of 1.91 is defined as being the acceptable limit of vehicle fatigue for continuous operation (approximately 0.6 to 0.9 G). (see GRAPH LEGEND, Figures 1 and 2.)

TABLE III

| Vehicle<br>Tire Group<br>Condition | Vehicle "Ride" Indices |              |              |              |               |             |              |           |
|------------------------------------|------------------------|--------------|--------------|--------------|---------------|-------------|--------------|-----------|
|                                    | Model "C" Tournapull   |              |              |              | "Coer" Tanker |             |              |           |
|                                    | A                      |              | F            |              | A             |             | F            |           |
| Inflation, Front, psig             | 40                     | 50           | 40           | 50           | 40            | 50          | 40           | 50        |
| Inflation, Rear, psig              | <u>30</u>              | <u>40</u>    | <u>30</u>    | <u>40</u>    | <u>30</u>     | <u>40</u>   | <u>30</u>    | <u>40</u> |
| Pavement                           | <u>"Ride" Index</u>    |              |              |              |               |             |              |           |
| #1, Smooth                         | 0.35                   | 0.68         | 0.51         | 0.50         | 0.22          | 0.27        | 0.31         | 0.29      |
| #2, Rough                          | <u>1.10</u>            | <u>1.10</u>  | <u>2.30*</u> | 0.80         | 0.57          | 0.65        | 0.80         | 0.75      |
| Secondary                          |                        |              |              |              |               |             |              |           |
| #1, Smooth                         | 0.54                   | 0.65         | 0.50         | <u>1.20</u>  | 0.22          | 0.56        | 0.20         | 0.18      |
| #2, Smooth                         | 0.52                   | <u>1.21</u>  | 0.37         | <u>1.40</u>  | 0.20          | <u>1.40</u> | 0.35         | 0.38      |
| #3, Rough                          | 0.85                   | <u>2.38*</u> | <u>0.92</u>  | <u>2.90*</u> | 0.51          | <u>0.90</u> | 0.58         | 0.62      |
| Cross-Country                      |                        |              |              |              |               |             |              |           |
| Rough                              | <u>2.70*</u>           | --           | <u>6.20*</u> | --           | <u>5.70*</u>  | --          | <u>2.90*</u> | --        |

|                       | Comparison of Mean Vehicle "Ride" Indices |             |             |             |              |               |       |
|-----------------------|---|-------------|-------------|-------------|--------------|---------------|-------|
|                       | Pavement                                  |             | Secondary   |             |              | Cross-Country |       |
|                       | Smooth                                    | Rough       | Smooth      | Smooth      | Rough        | Smooth        | Rough |
| Coer @ 40-30 psig     | 0.27                                      | 0.63        | 0.21        | 0.28        | 0.53         | <u>4.30*</u>  |       |
| "C" Pull @ 40-30 psig | 0.43                                      | <u>1.70</u> | 0.52        | 0.45        | 0.89         | <u>4.45*</u>  |       |
| Coer @ 50-40 psig     | 0.28                                      | 0.78        | 0.37        | 0.89        | 0.76         | --            |       |
| "C" Pull @ 50-40 psig | 0.59                                      | <u>0.95</u> | <u>0.93</u> | <u>1.31</u> | <u>2.64*</u> | --            |       |

Underlined values are in excess of acceptable human fatigue limits for continuous operation.

(\*) Asterisked values are in excess of acceptable human and vehicle fatigue limits for continuous operation.



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TEST RESULTS (Contd.)

Table IV summarizes the results of the Shallow Mud Traction Study (See Appendix 3, Mud Traction Study) of the directional tread conventional construction 29.5 - 25 tires and the non-directional tread radial ply 29.5 - 25 tires in terms of the influence of inflation pressure on tractive efficiency.

TABLE IV

| <u>Inflation Pressure</u> | <u>Maximum Drawbar, Lbs.</u> |                | <u>% Travel Efficiency @ Maximum Drawbar</u> |                | <u>Static Ground-Lug Pressure PSI(2)</u> |                |
|---------------------------|------------------------------|----------------|--|----------------|--|----------------|
|                           | <u>Group A</u>               | <u>Group F</u> | <u>Group A</u>                               | <u>Group F</u> | <u>Group A</u>                           | <u>Group F</u> |
| 55                        | 9800                         | 6100           | 17   | 26             | 228                                      | 113            |
| 45                        | 8200                         | 6800           | 30   | 31             | 146                                      | 85             |
| 35                        | 7800                         | 7150           | 30   | 27             | 109                                      | 62             |
| 25                        | 7600                         | 8750           | 40   | 32             | 87                                       | 56             |
| 15                        | (7550)(1)                    | 9800           | --   | 36             | 72                                       | 48             |

- (1) Extrapolated from inflation pressure-maximum drawbar curve of Groups A and F.
- (2) At 55 PSI the A Group penetrated to a depth of 2.25" in the crown area of the track and the F Group penetrated to a depth of 1.75" in the same area. At 25 PSI the A Group penetrated 0.25" evenly across track and the F Group penetrated to depth of 2.00" in the shoulder area of the track.

TEST RESULTS (Contd.)

Table V summarizes the calculated influence of the directional conventional tire (Group A) and the influence of the non-directional radial ply tire (Group F) on the shallow mud traction of the "Goer" Tanker.

TABLE V

Maximum Drawbar and Gradeability

| Inflation Pressure | 4 Wheels Driving |       |         |       | 2 Wheels Driving |       |         |       |
|--------------------|------------------|-------|---------|-------|------------------|-------|---------|-------|
|                    | Group A          |       | Group F |       | Group A          |       | Group F |       |
|                    | D.B.             | Grade | D.B.    | Grade | D.B.             | Grade | D.B.    | Grade |
| 55                 | 17950#           | 25%   | 11500#  | 16%   | 9600#            | 13%   | 6100#   | 8%    |
| 45                 | 15100            | 21    | 12200   | 17    | 8100             | 11    | 6500    | 9     |
| 35                 | 14350            | 20    | 13000   | 18    | 7700             | 11    | 6900    | 10    |
| 25                 | 13650            | 19    | 15800   | 22    | 7300             | 10    | 8400    | 12    |
| 15                 | 13650            | 19    | 17950   | 25    | 7250             | 10    | 9600    | 13    |

Maximum Drawbar and Gradeability at 75% Travel Efficiency

| Inflation Pressure | 4 Wheels Driving |       |         |       | 2 Wheels Driving |       |         |       |
|--------------------|------------------|-------|---------|-------|------------------|-------|---------|-------|
|                    | Group A          |       | Group F |       | Group A          |       | Group F |       |
|                    | D.B.             | Grade | D.B.    | Grade | D.B.             | Grade | D.B.    | Grade |
| 55                 | 8200#            | 12%   | 2800#   | 4%    | 4300#            | 6%    | 1500#   | 2%    |
| 45                 | 8600             | 12    | 6500    | 9     | 4600             | 6     | 3450    | 5     |
| 35                 | 9200             | 13    | 7900    | 11    | 5000             | 7     | 4200    | 6     |
| 25                 | 10800            | 15    | 8600    | 12    | 5750             | 8     | 4600    | 6     |
| 15                 | --               | --    | 11500   | 16    | --               | --    | 6100    | 8     |

D.B. = Drawbar

Grade = Gradeability

TEST RESULTS (Contd.)

Table VI summarizes the calculated performance of the "Goer" Tanker in terms of maximum traction (maximum performance) and at 75% travel efficiency.

TABLE VI

| <u>Pressure</u> | <u>4 Wheel Drive Comparative Performance Ratings</u> |                |                                |                |
|-----------------|--|----------------|--------------------------------|----------------|
|                 | <u>Maximum Performance</u>                           |                | <u>@ 75% Travel Efficiency</u> |                |
|                 | <u>Group A</u>                                       | <u>Group F</u> | <u>Group A</u>                 | <u>Group F</u> |
| 55              | 100%   | 64%            | 100%                           | 33%            |
| 45              | 100  | 80             | 100                            | 75             |
| 35              | 100  | 90             | 100                            | 85             |
| 25              | 100  | 115            | 100                            | 80             |
| 15              | 100  | 131            | --                             | --             |

# TEST RESULTS (Contd.)

Table VII summarizes the tire temperatures on pavement without regard for ambient or pavement temperatures as tire temperatures were recorded under equivalent conditions in each period.

TABLE VII

| 2,500 Mile<br>Test Period | Tread Temperature of Test Tires on Pavement      |         |         |         |         |         |         |         |         |         |
|---------------------------|--|---------|---------|---------|---------|---------|---------|---------|---------|---------|
|                           | Group A  |         | Group B |         | Group C |         | Group D |         | Group E |         |
|                           | Max. of  | Avg. of | Max. of | Avg. of | Max. of | Avg. of | Max. of | Avg. of | Max. of | Avg. of |
| 1st                       | Low temperatures recorded due to probe position. |         |         |         |         |         |         |         |         |         |
| 2nd, 3rd                  | 230  | 199     | 275*    | 182     | 224     | 195     | --      | --      | --      | --      |
| 4th                       | 220  | 198     | 245*    | 203     | 205     | 199     | --      | --      | --      | --      |
| 5th                       | 265*   | 209     | 240*    | 209     | 234     | 213     | --      | --      | --      | --      |
| Mean Temperature          | 202  |         |         | 198     |         | 202     |         |         |         |         |
| 6th                       | --   | --      | --      | --      | 200     | 189     | 216     | 203     | 256     | 232     |
| 7th                       | --   | --      | --      | --      | --      | --      | 233     | 216     | 265     | 242     |
| Mean Temperature          |  |         |         |         |         |         |         | 210     |         | 237     |

\* Areas influenced by tread condition.

TEST RESULTS (Contd.)

Table VIII summarizes a comparison of vehicle fuel consumption as an index of tire rolling resistance.

TABLE VIII

|         | <u>Pavement</u> | <u>Average Miles per Gallon<br/>Secondary &amp; Cross-Country</u> | <u>Over-All</u> |
|---------|-----------------|---|-----------------|
| Group A | 2.77            | 1.91  | 2.18            |
| Group B | 2.81            | 2.05  | 2.30            |
| Group C | 2.68            | 1.89  | 2.14            |

Over-All Rating % Based on Average Miles/Gallon

| <u>Group A</u> | <u>Group B</u> | <u>Group C</u> |
|----------------|----------------|----------------|
| 100%           | 106%           | 98%            |

## RECOMMENDATIONS

The scope of Project 20-1-110 has generated specific conclusions with respect to the tires and vehicles evaluated during this program. Deserving additional investigation to satisfy the specific questions arising from the results of this program are the following:

### Tread Wear and Durability

The directional radial ply construction (Group E) and the non-directional conventional construction (Group D) tires should be subjected to additional durability test mileage before a valid performance comparison can be drawn for all tires considered in Project 20-1-110.

### "Ride" Evaluation

The "Goer" Tanker vehicle exhibits a marked improvement in "Ride" over the commercial Model "C" Tournapull "test beds" on pavement and secondary roads, but not over cross-country trails with the inflation pressures recommended for the "Goer". As the "Goer" is equipped with a central self inflation system, all tires considered for "Goer" application should be judged in terms of cross-country "Goer" ride index vs inflation pressure curve in order to determine each tire group's tactical speed limit when negotiating cross-country.

### "Goer" Mud Traction

In shallow mud the non-directional radial ply tires (Group F) were found to be as effective as the directional conventional construction (Group A) tires when the non-directional tires were inflated at 15 psig and the directional tires were inflated at 55 psig. The effect of this marked difference in inflation pressure and consequent reduction in ground contact pressure for the Group F tires should be measured in deep mud where underbody clearance not tire traction may be the factor limiting mobility. The directional radial tires (Group E) and the non-directional conventional construction tires should be evaluated in both shallow and deep mud to determine the separate effects of radial ply versus conventional construction and non-directional versus directional tread on mud traction. The influence of vehicle configuration should be assessed under these same conditions by measuring the percent effectiveness of the "Goer" rear wheel drive in mud.

DISPOSITION OF TIRES SUBJECTED TO TEST

Group A, Firestone Super Ground Grip Goer H.D. Directional (Control)

| <u>Tire Code</u> | <u>Serial Number</u> | <u>Total<br/>Test Miles</u> | <u>Reason for Removal</u>        | <u>Replacement<br/>Tire</u> |
|------------------|----------------------|-----------------------------|----------------------------------|-----------------------------|
| A-1              | K 25300-14           | 10,022                      | Outside shoulder worn smooth.    | None                        |
| A-2              | K 25300-18           | 10,022                      | Both shoulders worn smooth.      | None                        |
| A-3              | K 25300-15           | 10,022                      | Inside shoulder worn smooth.     | None                        |
| A-4              | K 25300-16           | 10,022                      | Test terminated at this mileage. | None                        |

Group B, U.S. Royal Tactical M.S. Radial Ply Construction Non-Directional

| <u>Tire Code</u> | <u>Serial Number</u> | <u>Total<br/>Test Miles</u> | <u>Reason for Removal</u>                      | <u>Replacement<br/>Tire</u> |
|------------------|----------------------|-----------------------------|--|-----------------------------|
| B-1              | EX 1808              | 7,231                       | Air loss above flipper.                        | B-6                         |
| B-2              | XF 1867              | 10,876                      | Air loss at radial crack.                      | B-7                         |
| B-3              | GR 1122              | 6,097                       | Tread separation inside shoulder.              | B-5                         |
| B-4              | GR 1351              | 13,306                      | Air loss at radial crack.                      | None                        |
| B-5              | GR 1099              | 7,209                       | Test terminated.                               | None                        |
| B-6              | GR 1177              | 5,512                       | Tread separation and air loss at radial crack. | Non-Test Spare              |
| B-7              | GR 1037              | 2,430                       | Test terminated                                | None                        |

DISPOSITION OF TIRES SUBJECTED TO TEST (Contd.)

Group C, Firestone Super Ground Grip Goer Directional

| <u>Tire Code</u> | <u>Serial Number</u> | <u>Total<br/>Test Miles</u> | <u>Reason for Removal</u>                          | <u>Replacement<br/>Tire</u> |
|------------------|----------------------|-----------------------------|--|-----------------------------|
| C-1              | K 25500-5            | 15,040                      | Near worn smooth<br>condition outside<br>shoulder. | None                        |
| C-2              | K 25500-4            | 15,040                      | Outside shoulder<br>worn smooth.                   | None                        |
| C-3              | K 25500-3            | 15,040                      | Test terminated.                                   | None                        |
| C-4              | K 25500-2            | 15,040                      | Test terminated.                                   | None                        |

Group D, Firestone NDMS

| <u>Tire Code</u> | <u>Serial Number</u> | <u>Total<br/>Test Miles</u> | <u>Reason for Removal</u> | <u>Replacement<br/>Tire</u> |
|------------------|----------------------|-----------------------------|---------------------------|-----------------------------|
| D-1              | K 26400-5            | 7,509                       | Test terminated.          | None                        |
| D-2              | K 26400-4            | 7,509                       | Test terminated.          | None                        |
| D-3              | K 26400-1            | 7,509                       | Test terminated.          | None                        |
| D-4              | K 26400-3            | 7,509                       | Test terminated.          | None                        |

Group E, U.S. Royal Radial Ply Construction Directional

| <u>Tire Code</u> | <u>Serial Number</u> | <u>Total<br/>Test Miles</u> | <u>Reason for Removal</u> | <u>Replacement<br/>Tire</u> |
|------------------|----------------------|-----------------------------|---------------------------|-----------------------------|
| E-1              | CD 1732              | 2,541                       | Test terminated.          | None                        |
| E-2              | CD 1706              | 2,541                       | Test terminated.          | None                        |
| E-3              | CD 1714              | 2,541                       | Test terminated.          | None                        |
| E-4              | CD 1658              | 2,541                       | Test terminated.          | None                        |



# SUMMARY OF TIRE TREAD WEAR

## 1. Final

| Tire Group                 | Physical Dimensions |           |        |       |       |
|----------------------------|---------------------|-----------|--------|-------|-------|
|                            | A                   | B         | C      | D     | E     |
| Total Miles                | 10,022              | 13,305(1) | 15,040 | 7,509 | 2,541 |
| Cross Section Growth, %    | 1.1                 | 0.7(2)    | 1.6    | 1.7   | 0.0   |
| Outside Diameter Growth, % | 0.1                 | (3)       | 0.6    | (3)   | 0.2   |
| Final Shore "A" Hardness   | 57                  | 57(2)     | 64     | 62    | 63    |

| Tire Group                         | Tread Wear at Shoulders |      |      |      |      |
|------------------------------------|-------------------------|------|------|------|------|
|                                    | A(4)                    | B(5) | C(6) | D    | E    |
| Mils Loss, Group                   | 9912                    | 3296 | 8181 | 3686 | 1001 |
| Miles/Mil, Group                   | 6.1                     | 29.9 | 12.2 | 16.3 | 20.3 |
| Rating, Group (Based on Miles/Mil) | 100                     | 490  | 200  | 267  | 333  |
| Mils Loss, Front                   | 4256                    | 1414 | 3385 | 1724 | 491  |
| Miles/Mil, Front                   | 7.1                     | 35.4 | 14.8 | 17.4 | 20.7 |
| Rating, Front (Based on Miles/Mil) | 100                     | 499  | 208  | 245  | 292  |
| Mils Loss, Rear                    | 5656                    | 1882 | 4796 | 1962 | 510  |
| Miles/Mil, Rear                    | 5.3                     | 25.7 | 10.4 | 15.3 | 19.9 |
| Rating, Rear (Based on Miles/Mil)  | 100                     | 485  | 196  | 289  | 375  |
| % Worn, Group                      | 79.2                    | 31.0 | 65.3 | 32.3 | 8.4  |
| % Worn, Front                      | 34.0                    | 13.3 | 27.0 | 15.1 | 4.1  |
| % Worn, Rear                       | 45.2                    | 17.7 | 38.3 | 17.1 | 4.3  |

- (1) Tire B-4 accumulated 13,306 test miles before failure. All other original test tires and one replacement tire failed prior to this mileage.
- (2) Based on the seven samples tested.
- (3) Due to tire design no crown measurements could be taken to correct Outside Diameter on these groups.
- (4) One or both of the shoulder measurement areas had worn away on three of the four test tires at 10,022 test miles. Figures shown represent wear rates through 7,522 test miles (last measurement period before worn smooth condition).
- (5) Figures are based on the performance of the seven tire samples at the last valid measurement period of each tire.
- (6) Figures based on 12,525 mile measurement period due to one tire worn smooth at 15,040 mile measurement period.

## SUMMARY OF TIRE TREAD WEAR (Contd.)

### 1. Final (Contd.)

As the only measurement positions common to all tire groups tested were the shoulders it was felt that a basis of comparison should be drawn from these data; however, even this must be weighed by the fact that there is a wide variation in mileage between the individual groups tested and the ratings even though based on miles per mil are on a total mileage; therefore, the figures do not reflect a true figure as it would if all tires had run equal miles.

A further comparison can be made on the three groups of tires whose design permitted a crown measurement. The following data indicates the tread wear across the tread face rather than in the fastest wearing area.

| Tire Group                         | Tread Wear at Shoulders and Crown |        |       |
|------------------------------------|-----------------------------------|--------|-------|
|                                    | A                                 | C      | E     |
| Total Miles                        | 7,522                             | 12,525 | 2,541 |
| Mils Loss, Group                   | 11351                             | 9861   | 1594  |
| Miles/Mil, Group                   | 8.0                               | 15.2   | 19.1  |
| Rating, Group (Based on Miles/Mil) | 100                               | 190    | 239   |
| Mils Loss, Front                   | 5179                              | 4347   | 787   |
| Miles/Mil, Front                   | 8.7                               | 17.3   | 19.4  |
| Rating, Front (Based on Miles/Mil) | 100                               | 199    | 223   |
| Mils Loss, Rear                    | 6172                              | 5514   | 807   |
| Miles/Mil, Rear                    | 7.3                               | 13.4   | 18.9  |
| Rating, Rear (Based on Miles/Mil)  | 100                               | 184    | 259   |
| % Worn, Group                      | 61.3                              | 53.2   | 8.9   |
| % Worn, Front                      | 28.0                              | 23.5   | 4.4   |
| % Worn, Rear                       | 33.3                              | 29.7   | 4.5   |

# SUMMARY OF TIRE TREAD WEAR (Contd.)

## 2. By Period

Tread wear measurements are based on two shoulder measurement locations on the B Group (U.S.) tires and on two and three locations, two shoulder and one crown, on the A and C Groups (Firestone). The shoulder measurements are located 9 inches each side of crown, and are taken in a position around the circumference of the tire. The A, B and C Groups are compared on the basis of two measurement locations and the A and C Groups are additionally compared on the basis of three measurement locations.

| Tire Group             | Firestone |       |       |      | U.S.     |
|------------------------|-----------|-------|-------|------|----------|
|                        | A         |       | C     |      | B        |
| Miles @ Meas.          | 2,520     |       | 2,520 |      | 2,520    |
| No. of Meas. Locations | 2         | 3     | 2     | 3    | 2        |
| Mils Loss (Group)      | 2239      | 2862  | 848   | 1465 | 584      |
| Miles/Mil (Group)      | 9.0       | 10.6  | 23.8  | 20.6 | 34.5     |
| % Worn (Group)         | 17.9      | 15.5  | 6.8   | 7.9  | 5.5      |
| Mils Loss (Front)      | 1039      | 1416  | 356   | 719  | 331      |
| Miles/Mil (Front)      | 9.7       | 10.7  | 28.3  | 21.0 | 30.5     |
| % Worn (Front)         | 16.5      | 15.2  | 5.7   | 7.8  | 6.3      |
| Mils Loss (Rear)       | 1200      | 1446  | 492   | 746  | 253      |
| Miles/Mil (Rear)       | 8.4       | 10.5  | 20.5  | 20.3 | 39.8     |
| % Worn (Rear)          | 19.1      | 15.7  | 7.9   | 8.1  | 4.7      |
| Miles @ Meas.          | 5,022     |       | 5,122 |      | 5,022    |
| Mils Loss (Group)      | 6043      | 6177  | 2643  | 3508 | 1243     |
| Miles/Mil (Group)      | 6.7       | 8.0   | 15.2  | 17.2 | 32.3     |
| % Worn (Group)         | 48.2      | 37.7  | 21.1  | 18.9 | 11.7     |
| Mils Loss (Front)      | 2657      | 3180  | 1215  | 1611 | 539      |
| Miles/Mil (Front)      | 7.6       | 9.5   | 10.5  | 17.8 | 33.5     |
| % Worn (Front)         | 42.2      | 34.2  | 19.4  | 18.2 | 11.3     |
| Mils Loss (Rear)       | 3386      | 3797  | 1428  | 1897 | 644      |
| Miles/Mil (Rear)       | 6.0       | 7.9   | 14.0  | 16.6 | 31.2     |
| % Worn (Rear)          | 54.1      | 41.1  | 22.9  | 19.6 | 12.0     |
| Miles @ Meas.          | 7,522     |       | 7,522 |      | 7,498(1) |
| Mils Loss (Group)      | 9912      | 11351 | 4318  | 5404 | 1808     |
| Miles/Mil (Group)      | 6.1       | 8.0   | 13.6  | 16.8 | 32.9     |
| % Worn (Group)(2)      | 79.2      | 61.3  | 34.6  | 29.9 | 13.6     |
| Mils Loss (Front)      | 4256      | 5179  | 1879  | 2499 | 944      |
| Miles/Mil (Front)      | 7.1       | 8.7   | 16.0  | 18.1 | 31.7     |
| % Worn in Front(2)     | 34.0      | 28.0  | 15.0  | 13.5 | 7.1      |
| Mils Loss (Rear)       | 5656      | 6172  | 2439  | 2905 | 864      |
| Miles/Mil (Rear)       | 5.3       | 7.3   | 12.2  | 15.5 | 34.1     |
| % Worn in Rear(2)      | 45.2      | 33.3  | 19.6  | 15.7 | 6.5      |

(1) Due to tire failures in this group 24 miles of cross-country operation was lost during tire replacement; therefore, these figures are based on 5 tires.

(2) % Worn =  $\frac{\text{Total Mils Loss}}{\text{Total Mils Available}} \times 100$

# SUMMARY OF TIRE TREAD WEAR (Contd.)

## 2. By Period (Contd.)

| Tire Group             | Firestone |        |      | U.S.      |
|------------------------|-----------|--------|------|-----------|
|                        | A         | C      |      | B         |
| Miles @ Meas.          | 10,022    | 10,022 |      | 10,024(1) |
| No. of Meas. Locations | 1*        | 2      | 3    | 2         |
| Mils Loss (Group)      | 2429      | 6210   | 7551 | 2549      |
| Miles/Mil (Group)      | 16.5      | 12.9   | 15.9 | 31.5      |
| % Worn (Group)(2)      | 40.5      | 49.5   | 40.8 | 16.0      |
| Mils Loss (Front)      | 1578      | 2589   | 3394 | 1140      |
| Miles/Mil (Front)      | 12.7      | 15.5   | 17.7 | 35.2      |
| % Worn in Front(2)     | 26.3      | 20.7   | 18.3 | 7.1       |
| Mils Loss (Rear)       | 851       | 3621   | 4157 | 1409      |
| Miles/Mil (Rear)       | 23.6      | 11.1   | 14.5 | 28.5      |
| % Worn in Rear(2)      | 14.3      | 28.9   | 22.4 | 8.8       |

| Tire Group             | Firestone |      | U.S.   | Firestone |
|------------------------|-----------|------|--------|-----------|
|                        | C         |      | B(3)   | D         |
| Miles @ Meas.          | 12,525    |      | 12,527 | 2,503     |
| No. of Meas. Locations | 2         | 3    | 2      | 2         |
| Mils Loss (Group)      | 8181      | 9861 | 3296   | 1357      |
| Miles/Mil (Group)      | 12.2      | 15.2 | 29.9   | 14.8      |
| % Worn (Group)(2)      | 65.3      | 53.2 | 31.0   | 11.9      |
| Mils Loss (Front)      | 3385      | 4347 | 1414   | 791       |
| Miles/Mil (Front)      | 14.8      | 17.3 | 35.4   | 12.7      |
| % Worn in Front(2)     | 27.0      | 23.5 | 13.3   | 6.9       |
| Mils Loss (Rear)       | 4796      | 5514 | 1882   | 566       |
| Miles/Mil (Rear)       | 10.5      | 13.6 | 25.7   | 17.7      |
| % Worn in Rear(2)      | 38.3      | 29.7 | 17.7   | 5.0       |

\* Some shoulder measurement positions worn away, negating group averages for 2 and 3 locations. Figures represent crown measurements only.

(1) Figures for B Group based on 6 tires.

(2) % Worn =  $\frac{\text{Total Mils Loss}}{\text{Total Mils Available}} \times 100$

(3) Figures for B Group based on 7 tires.

SUMMARY OF TIRE TREAD WEAR (Contd.)

2. By Period (Contd.)

| Tire Group             | Firestone<br>C | U. S.<br>B(1) | Firestone<br>D |
|------------------------|----------------|---------------|----------------|
| Miles @ Meas.          | 15,040         | 13,306        | 5,003          |
| No. of Meas. Locations | 1*             | 2             | 2              |
| Mils Loss (Group)      | 2161           | 3296          | 2286           |
| Miles/Mil (Group)      | 27.8           | 29.9          | 17.5           |
| % Worn (Group)(2)      | 36.0           | 31.0          | 20.0           |
| Mils Loss (Front)      | 1146           | 1414          | 1185           |
| Miles/Mil (Front)      | 26.2           | 35.4          | 16.9           |
| % Worn in Front(2)     | 19.1           | 13.3          | 10.4           |
| Mils Loss (Rear)       | 1015           | 1882          | 1101           |
| Miles/Mil (Rear)       | 29.6           | 25.7          | 18.2           |
| % Worn in Rear(2)      | 16.9           | 17.7          | 9.6            |

| Tire Group             | Firestone<br>D | U.S.<br>E |      |
|------------------------|----------------|-----------|------|
| Miles @ Meas.          | 7,509          | 2,541     |      |
| No. of Meas. Locations | 2              | 2         | 3    |
| Mils Loss (Group)      | 3686           | 1001      | 1594 |
| Miles/Mil (Group)      | 16.3           | 20.3      | 19.1 |
| % Worn (Group)(2)      | 32.3           | 8.4       | 8.9  |
| Mils Loss (Front)      | 1724           | 491       | 787  |
| Miles/Mil (Front)      | 17.4           | 20.7      | 19.4 |
| % Worn in Front(2)     | 15.1           | 4.1       | 4.4  |
| Mils Loss (Rear)       | 1962           | 510       | 807  |
| Miles/Mil (Rear)       | 15.3           | 19.9      | 18.9 |
| % Worn in Rear (2)     | 17.1           | 4.3       | 4.5  |

\* One tire in group had shoulder measurement positions worn away, negating group averages for 2 and 3 locations. Figures represent crown measurements only.

(1) Figures are based on the performance of the seven tire samples at the last valid measurement period of each tire.

(2) % Worn =  $\frac{\text{Total Mils Loss}}{\text{Total Mils Available}} \times 100$

# SUMMARY OF TIRE TEMPERATURES

Heat Build-up 1st Period: After tire inflation pressures had been determined tire tread temperatures were taken for six consecutive operating days immediately after the vehicles had completed the pavement portion of the day shift operation. Pavement tire temperatures and pressures for the 2,520 miles covered by 1st period of operation are as follows:

## Averages of Tread Temperatures (°F) and Tire Pressures (psig)

| Tire Group      |     |     | A-Firestone Control |      |      |      |       | B-U.S. Rubber Exp. |      |      |      | C-Firestone Exp. |      |      |      |      |      |    |  |    |
|-----------------|-----|-----|---------------------|------|------|------|-------|--------------------|------|------|------|------------------|------|------|------|------|------|----|--|----|
| Vehicle         |     |     | C-1                 |      |      |      |       | C-2                |      |      |      | C-3              |      |      |      |      |      |    |  |    |
| psig Cold Start |     |     | F                   | 35   | R    |      |       | 25                 | F    | 40   | R    |                  |      | 25   | F    | 35   | R    |    |  | 25 |
| Pave            | Amb | °F  | psig                |      |      |      |       | °F                 | psig |      |      |                  | °F   | psig |      |      |      | °F |  |    |
| °F              | (1) | (2) | Cold                | End  | Inc  | Temp |       | Cold               | End  | Inc  | Temp |                  | Cold | End  | Inc  | Temp |      |    |  |    |
| 71              | 55  | 37  | F                   | 36.1 | 48.6 | 12.5 | 164.2 |                    | 41.0 | 50.2 | 9.2  | 148.0            |      | 36.0 | 47.8 | 11.8 | 161. |    |  |    |
|                 |     |     | R                   | 26.0 | 36.3 | 10.3 | 177.7 |                    | 26.1 | 34.1 | 8.0  | 155.9            |      | 25.9 | 34.8 | 8.9  | 182. |    |  |    |

(1) At time of temperature measurement.

(2) At cold starting time.

Heat Build-up 2nd and 3rd Periods: Pavement tire temperatures and pressures for the 5,002 miles covered by these periods of operation.

| Tire Group                                    | Group A              | Group B*               | Group C              |
|---|----------------------|------------------------|----------------------|
| Maximum Tire Temperature                      | 230°F                | 211°F                  | 224°F                |
| Average Tire Temperature                      | 199°F                | 182°F                  | 195°F                |
| Maximum Tire Pressure                         | 51 psig<br>(35 cold) | 53.5 psig<br>(40 cold) | 58 psig<br>(40 cold) |
| Average Tire Pressure Build-up<br>(All Tires) | 13 psig              | 11 psig                | 13 psig              |
| Maximum Ambient                               | 67°F                 | 67°F                   | 67°F                 |
| Average Ambient                               | 60°F                 | 60°F                   | 60°F                 |

\* 275°F maximum at separated area.

Note: Average tread temperatures for secondary road operation are Group A, 199°F; Group B, 186°F; Group C, 189°F.

### SUMMARY OF TIRE TEMPERATURES (Contd.)

Heat Build-up 4th Period: Pavement tire temperatures and pressures for the 2,500 miles covered by this period of operation.

| Tire Group   | <u>Group A</u>    | <u>Group B</u>    | <u>Group C</u>    |
|--|-------------------|-------------------|-------------------|
| Maximum Tire Temperature °F                        | 220               | 245               | 205               |
| Average Tire Temperature °F                        | 198               | 203               | 199               |
| Maximum Tire Pressure, psig                        | 51.5<br>(35 cold) | 56.0<br>(40 cold) | 58.0<br>(40 cold) |
| Average Tire Pressure Build-up<br>(All Tires) psig | 13                | 12                | 14                |
| Maximum Ambient Temperature °F                     | 70                | 70                | 70                |
| Average Ambient Temperature °F                     | 62                | 62                | 62                |

Heat Build-up 5th Period: Pavement tire temperatures and pressures for the 2,500 miles covered by this period of operation.

| Tire Group   | <u>Group B</u>    | <u>Group C</u>    | <u>Group D</u>       |
|--|-------------------|-------------------|----------------------|
| Maximum Tire Temperature °F                        | 265(1)            | 240               | 234                  |
| Average Tire Temperature °F                        | 209               | 209               | 213                  |
| Maximum Tire Pressure, psig                        | 52.0<br>(40 cold) | 55.0<br>(40 cold) | 52.0<br>(40 cold)(2) |
| Average Tire Pressure Build-up<br>(All Tires) psig | 11                | 14                | 12                   |
| Maximum Ambient Temperature °F                     | 83                | 84                | 83                   |
| Average Ambient Temperature °F                     | 82                | 83                | 74                   |

(1) See TEST DATA, 3. Tread Temperatures & Tire Pressures.

(2) Tire pressures were originally set at 35 psig front and 25 psig rear (cold starting). On 5/18/63 at 716 total test miles tire inflation (cold starting) was increased to 40.0 psig front and 30.0 psig rear.

# SUMMARY OF TIRE TEMPERATURES (Contd.)

Heat Build-up 6th Period: Pavement tire temperatures and pressures for the 2,500 miles covered by this period of operation.

| Tire Group   | <u>Group C(1)</u> | <u>Group D</u>    | <u>Group E</u>    |
|--|-------------------|-------------------|-------------------|
| Maximum Tire Temperature °F                        | 200               | 216               | 256               |
| Average Tire Temperature °F                        | 189               | 203               | 232               |
| Maximum Tire Pressure, psig                        | 52.5<br>(40 cold) | 56.0<br>(40 cold) | 54.0<br>(40 cold) |
| Average Tire Pressure Build-up<br>(All Tires) psig | 11                | 12                | 11                |
| Maximum Ambient Temperature °F                     | 55                | 84                | 84                |
| Average Ambient Temperature °F                     | 55                | 69                | 69                |

Heat Build-up 7th Period: Pavement tire temperatures and pressures for the 2,500 miles covered by this period of operation.

| Tire Group   | <u>Group D(1)</u> | <u>Group E(1)</u> |
|--|-------------------|-------------------|
| Maximum Tire Temperature °F                        | 233               | 265               |
| Average Tire Temperature °F                        | 216               | 242               |
| Maximum Tire Pressure, psig                        | 55.0<br>(40 cold) | 55.0<br>(40 cold) |
| Average Tire Pressure Build-up<br>(All Tires) psig | 13                | 12                |
| Maximum Ambient Temperature °F                     | 76                | 76                |
| Average Ambient Temperature °F                     | 76                | 76                |

(1) Tire temperatures were only taken once during this period.



TIRE ROLLING RESISTANCE EXPRESSED IN MILES PER GALLON

At the completion of three measurement and rotation periods wherein each tire group operated one period on each vehicle the following fuel consumption data was compiled.

|  | <u>Group A</u> | <u>Group B</u> | <u>Group C</u> |
|--|----------------|----------------|----------------|
| Miles per Gallon, Pavement                       | 2.77           | 2.81           | 2.68           |
| Rating   | 100            | 101            | 97             |
| Miles per Gallon, Secondary<br>and Cross-Country | 1.91           | 2.05           | 1.89           |
| Rating   | 100            | 107            | 99             |
| Miles per Gallon, Total                          | 2.18           | 2.30           | 2.14           |
| Rating   | 100            | 106            | 98             |

# DRIVER EVALUATION OF "RIDE" BY TIRE GROUPS

The first driver reaction to ride by groups was taken at the end of the 7,500 mile period; wherein each driver polled had driven each tire group on each test vehicle thereby eliminating the possibility of one vehicle influencing tire ride.

The following table indicates drivers observed ride:

Group C - Best on pavement and secondary.

Group B - Poorest on pavement and secondary.

Group A, B, C - Equal on Cross-country.

The next poll taken was at the 10,000 mile point and was a rating by the drivers of the three tire groups on the courses on which they had the most driving time. Those who placed the B Group in first place on pavement and secondary qualified the rating to the speed ranges above or below that in which lope was developed.

| Preference<br>Driver # | Pavement |          |          |          |          |          |          | Secondary |          |          |          |          |          |          | Cross-Country |          |          |          |          |          |          |
|------------------------|----------|----------|----------|----------|----------|----------|----------|-----------|----------|----------|----------|----------|----------|----------|---------------|----------|----------|----------|----------|----------|----------|
|                        | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> | <u>5</u> | <u>6</u> | <u>7</u> | <u>1</u>  | <u>2</u> | <u>3</u> | <u>4</u> | <u>5</u> | <u>6</u> | <u>7</u> | <u>1</u>      | <u>2</u> | <u>3</u> | <u>4</u> | <u>5</u> | <u>6</u> | <u>7</u> |
| 1st                    | B        | C        | -        | C        | C        | -        | -        | C         | C        | A        | B        | B        | C        | A        | C             | -        | C        | B        | -        | C        | C        |
| 2nd                    | C        | A        | -        | B        | A        | -        | -        | A         | A        | C        | C        | A        | A        | C        | A             | -        | A        | C        | -        | A        | A        |
| 3rd                    | A        | B        | -        | A        | B        | -        | -        | B         | B        | B        | A        | C        | B        | B        | B             | -        | B        | A        | -        | B        | B        |

As tire groups were removed from test and substitute groups inserted a final observed rating was necessary covering the new groups.

The following table shows a tire Group F which was of similar construction and design as the Group B tires which were removed from test prematurely due to failures:

| Preference<br>Driver # | Pavement |          |          |          |          |          |          | Secondary |          |          |          |          |          |          | Cross-Country |          |          |          |          |          |          |
|------------------------|----------|----------|----------|----------|----------|----------|----------|-----------|----------|----------|----------|----------|----------|----------|---------------|----------|----------|----------|----------|----------|----------|
|                        | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> | <u>5</u> | <u>6</u> | <u>7</u> | <u>1</u>  | <u>2</u> | <u>3</u> | <u>4</u> | <u>5</u> | <u>6</u> | <u>7</u> | <u>1</u>      | <u>2</u> | <u>3</u> | <u>4</u> | <u>5</u> | <u>6</u> | <u>7</u> |
| 1st                    | DE       | DE       | -        | DE       | DE       | -        | -        | E         | E        | DE       | E        | DE       | E        | -        | FE            | -        | FE       | FE       | -        | FE       | FE       |
| 2nd                    | F        | F        | -        | F        | F        | -        | -        | DF        | DF       | F        | DF       | F        | DF       | -        | D             | -        | -        | D        | D        | D        | D        |

## TEST PROGRAM

### Test Courses

Pavement Operation - The first week of test operation on pavement was conducted on Highway 95A from Silver Springs to the Fort Churchill turnaround. This provided 7.1 miles of pavement operation per turnaround; however, due to high lope exciters which prevented operation of over 1800 RPM, 5th gear at the Fort Churchill end of course it was deemed necessary to eliminate the last 3.1 miles of the original course, and a new turnaround was established at the Weeks road (secondary test course) junction.

After 6540 total miles of pavement operation and 908 laps the paved course #1 from Silver Springs to Weeks turnaround on Highway 95A deteriorated to the point that a course change was required.

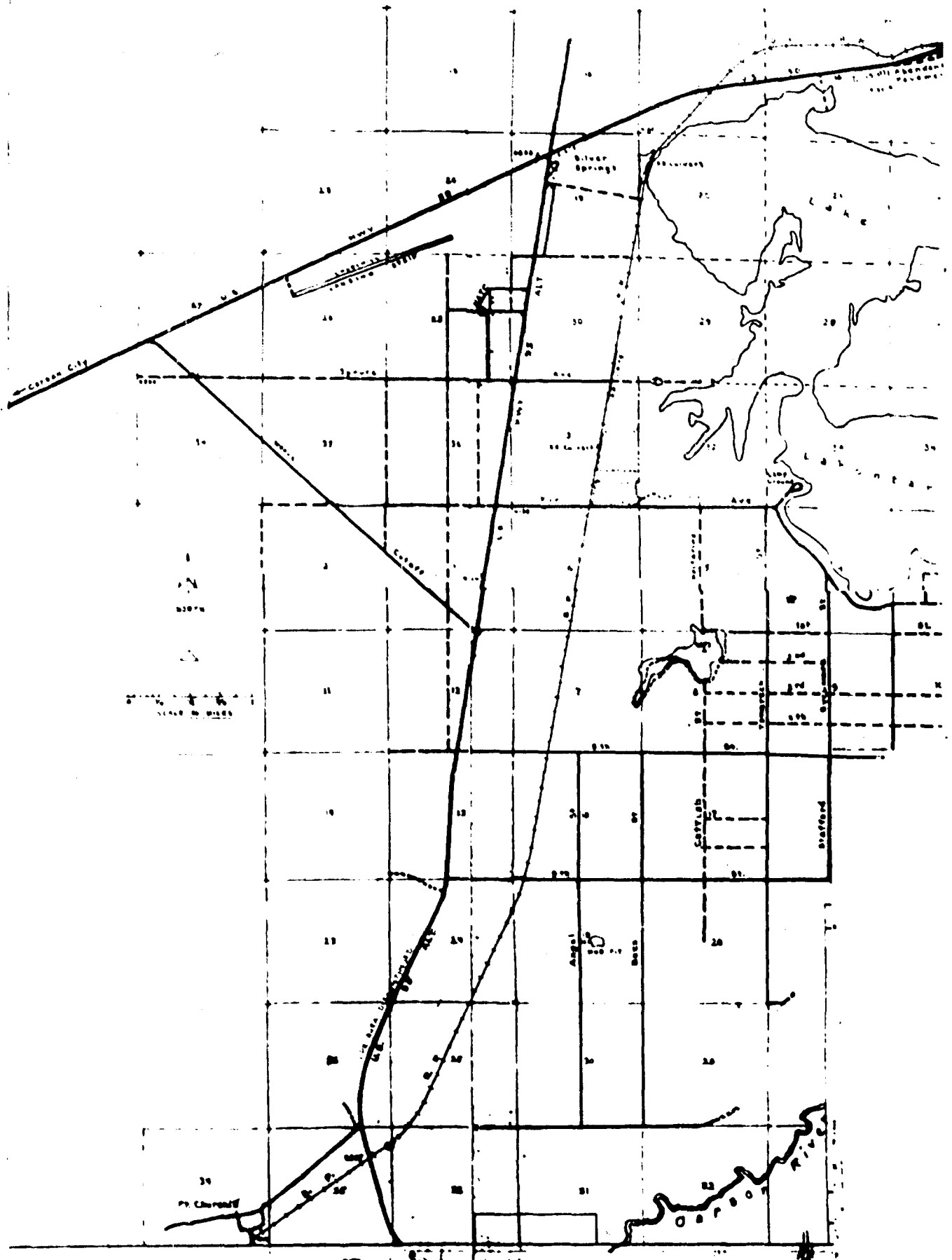
The new route (#2) on abandoned paved highway from Silver Springs to junction of Highways 50 and 95 permitted 194 miles of pavement operation per shift instead of the 104 miles per shift on test course #1, which was limited by Highway Department permit. The length of test course #2 permits an average vehicle speed of 25.8 MPH as opposed to 24.5 MPH on test course #1.

Secondary Operation - A variety of courses was used throughout the test due to the destructive forces applied by the vehicles and aggressive tire designs. As one area became a lope generator wherein maximum speed could not be sustained without undue forces on vehicle and driver, an identical test area was used to permit the destroyed course to be maintained. A noticeable improvement in course condition developed in the third 2500 mile period. The courses appeared to be "packing" a more stable surface and the cause is attributed to the considerable reduction in the aggressive lug penetration of the A and C tire groups due to wear. This same condition was also apparent on the cross-country course.

Cross-Country Operation - The same course was maintained throughout the test with the exception of the alkali flats at the north end of course which became impassable during rain storms.

The following map indicates test courses used during test with the exception of pavement course #2.

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Upper Photograph

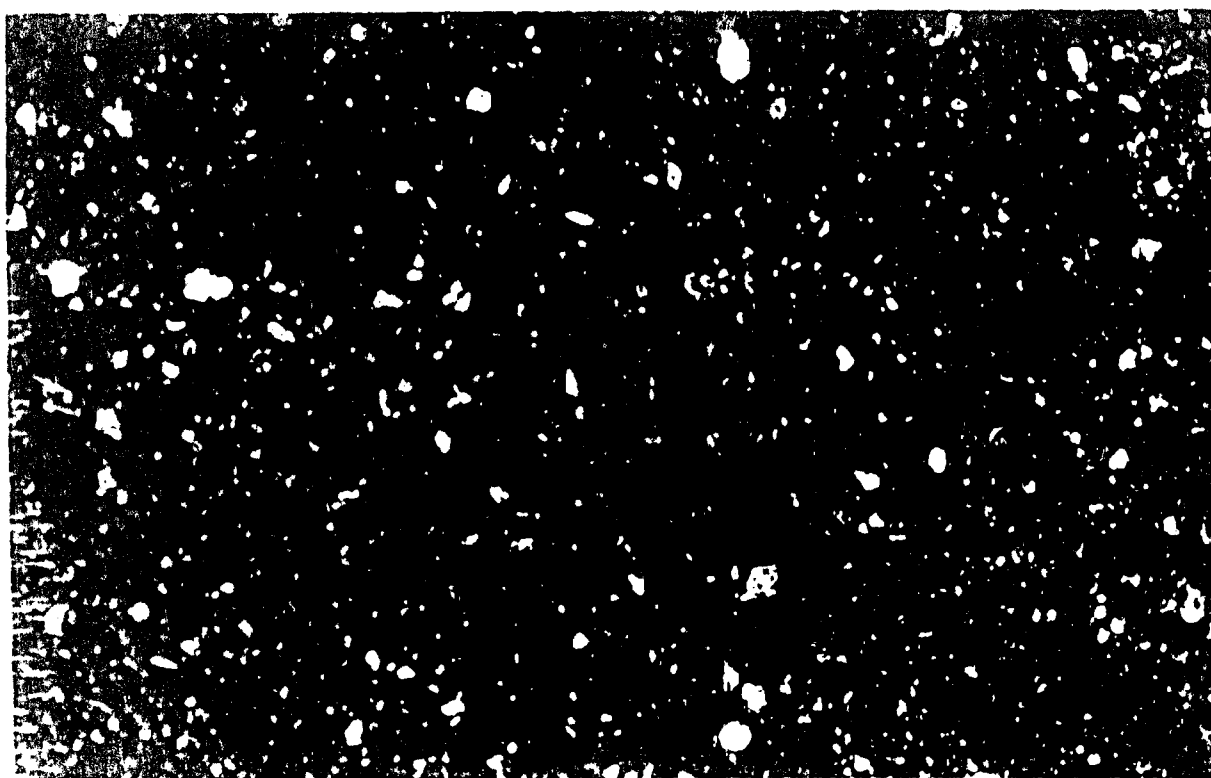
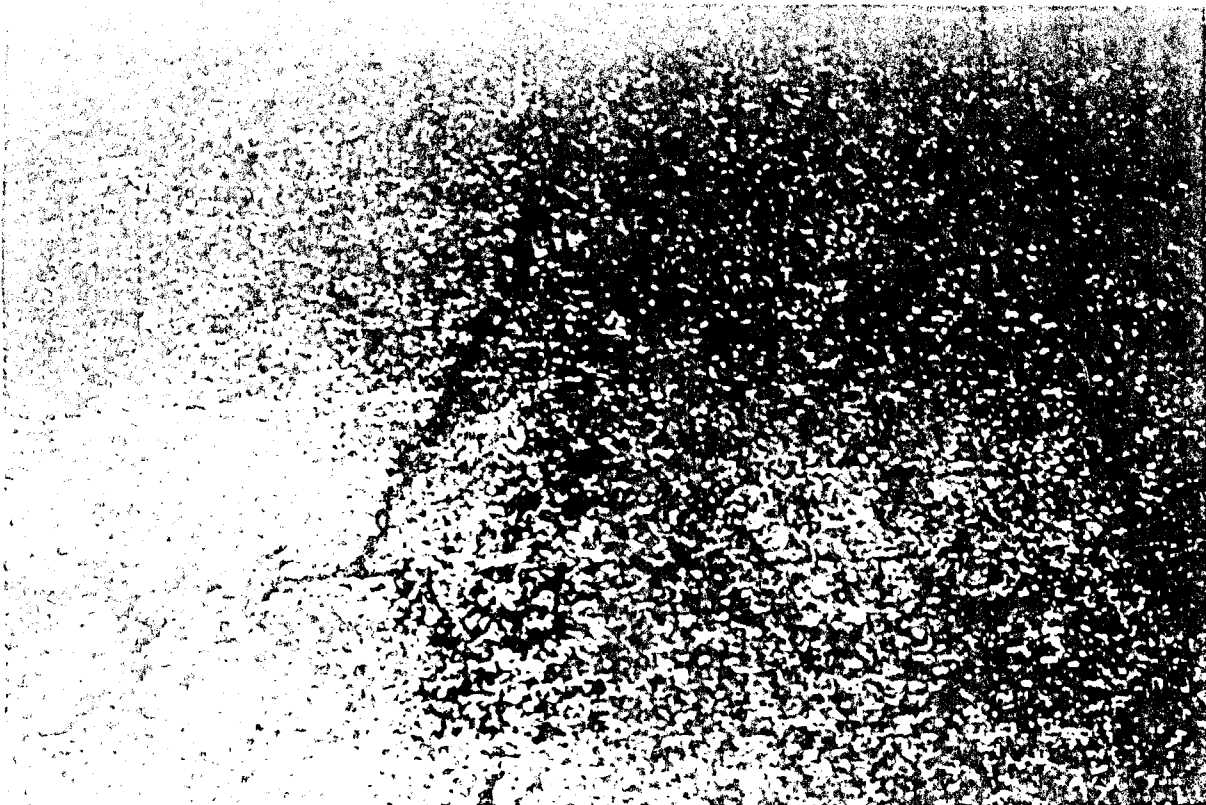
Pavement Deterioration of Course #2  
Produced by the Random Cyclic Excitations of Test Vehicles

Lower Photograph

Texture of Pavement Surface Course #2

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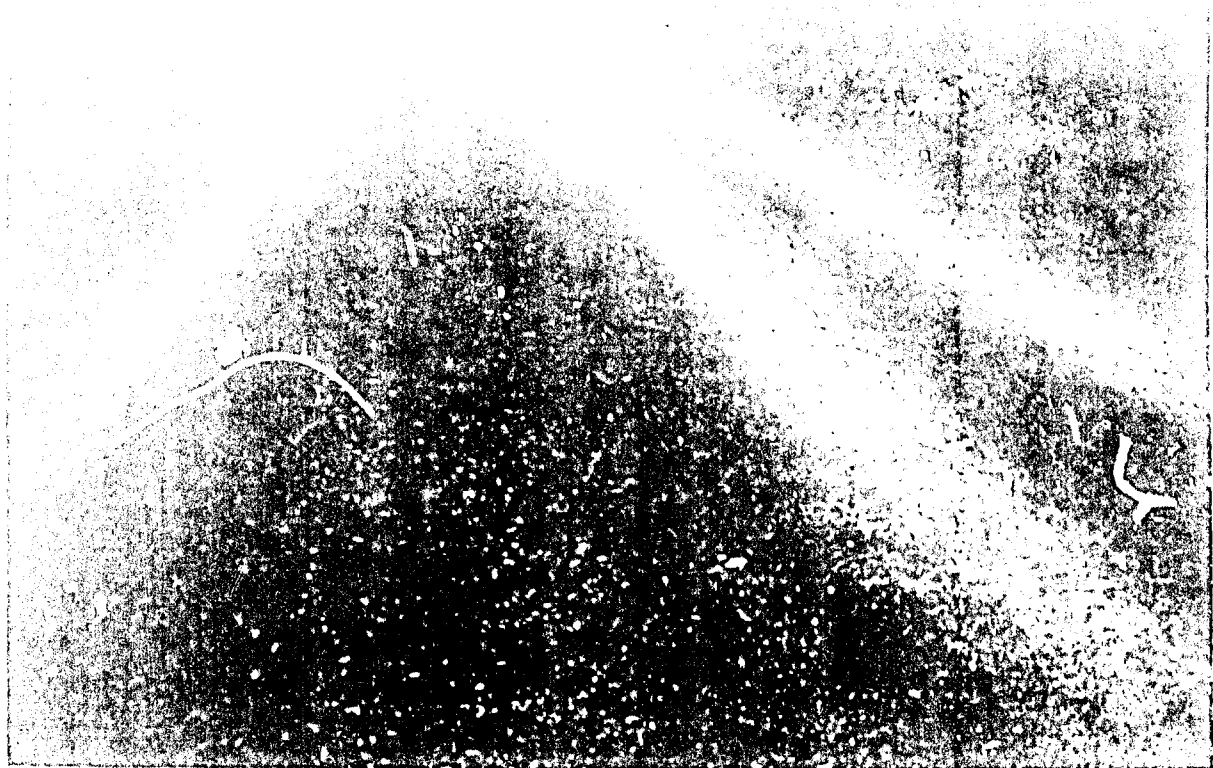
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Project 20-1-110

Upper Photograph  
Secondary Gravel Test Course (Weeks Road)

Lower Photograph  
Cross-Country Test Course Hill Section



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## TEST PROGRAM (Contd.)

### Test Speeds

Cross-Country - Maximum allowed by test course and vehicle conditions.

Gravel-Secondary - Maximum allowed by test course and vehicle conditions.

Highway - Maximum allowed by test course and vehicle conditions.

Tire Break-in. Vehicle operating speeds were reduced to one-half of required test speeds for first 16 hours of operation.

### Tire Inflation Pressures

At start of test, tire pressures were established for all three groups at 35 psig, front axle and 30 psig, rear axle. It was found that on pavement and secondary road operation the degree of lops or bounce of the vehicles was so extreme that continued operation was not safe for personnel nor could the equipment withstand continued impact of the G forces involved. Tire pressures were varied in 5 psig increments, front and rear, at cold start as tabulated below, until a combination was established for each tire group that would permit safe convoy operation of the three vehicles at acceptable speeds for each type of terrain.

| Tire Group | Miles at psig Settings |    |    |       |    |    |       |    |    |
|------------|------------------------|----|----|-------|----|----|-------|----|----|
|            | A                      |    |    | B     |    |    | C     |    |    |
|            | Miles                  | F  | R  | Miles | F  | R  | Miles | F  | R  |
|            | 446                    | 35 | 30 | 359   | 35 | 30 | 446   | 35 | 20 |
|            | 2074                   | 35 | 25 |       | 30 | 30 | 2074  | 35 | 25 |
|            |                        |    |    |       | 35 | 25 |       |    |    |
|            |                        |    |    | 476   | 35 | 35 |       |    |    |
|            |                        |    |    |       | 35 | 45 |       |    |    |
|            |                        |    |    |       | 40 | 45 |       |    |    |
|            |                        |    |    |       | 50 | 45 |       |    |    |
|            |                        |    |    |       | 40 | 20 |       |    |    |
|            |                        |    |    | 1685  | 40 | 25 |       |    |    |

On 4 March 1963 at 3267 test miles at the beginning of 1st shift, tire inflation of the C Group tires was raised, at the manufacturer's request, by 5 psig (40 front, 30 rear) to alleviate fast shoulder wear.

When Groups D and E entered the test program the tire inflation pressures were established at 40 psig front and 30 psig rear for purposes of tread wear evaluation.

TEST PROGRAM (Contd.)

Test Vehicles

Three (3) commercial vehicles were loaded to simulate a "Goer" Tanker GVW of 70-72000 lbs. Axle load distribution was approximately 54% front and 46% rear. Test bed vehicles had equivalent torque and braking characteristics. With the exception of failed parts replacement the vehicles were maintained throughout test by the Nevada Automotive Test Center using those methods approved by the vehicle manufacturer.

Vehicle Weights

| Vehicle              | <u>C-1</u>    | <u>C-2</u>    | <u>C-3</u>    | <u>"Goer"(1)</u> |
|----------------------|---------------|---------------|---------------|------------------|
| Front Axle, Lbs.     | 38,800        | 39,000        | 38,400        | 38,370           |
| Rear Axle, Lbs.      | <u>32,000</u> | <u>31,900</u> | <u>31,000</u> | <u>33,450</u>    |
| Gross Vehicle Weight | 70,000        | 70,900        | 69,400        | 71,820           |
| Left Rear, Lbs.      | 16,000        | 16,000        | 15,000        | --               |
| Right Rear, Lbs.     | <u>16,250</u> | <u>16,200</u> | <u>15,600</u> | --               |
|                      | 32,250        | 32,200        | 30,600        |                  |

(1) Goer vehicle was used in engineering studies and not on tire durability tests.

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TEST PROGRAM (Contd.)

Test Mileage

Under the original test directive each group of tires was to be run 20,000 miles divided as follows:

- 20% - Cross-Country
- 40% - Secondary Gravel
- 40% - Highway

The following table indicates the miles accumulated and average miles per hour in each period throughout test.

| Period | Groups Run             | Highway<br>Pavement |          | Secondary<br>Gravel |          | Cross<br>Country |          | Total |          |
|--------|------------------------|---------------------|----------|---------------------|----------|------------------|----------|-------|----------|
|        |                        | Miles               | Avg. MPH | Miles               | Avg. MPH | Miles            | Avg. MPH | Miles | Avg. MPH |
| 1st    | A, B & C               | 1,000               | 21.9     | 1,000               | 19.1     | 520              | 9.2      | 2,520 | 16.3     |
| 2nd    | A, B & C               | 1,000               | 24.4     | 1,002               | 20.7     | 500              | 8.9      | 2,502 | 17.4     |
| 3rd    | A, B & C               | 1,000               | 22.7*    | 1,000               | 19.9*    | 500(1)           | 9.6      | 2,500 | 17.1     |
| 4th    | A, B & C               | 1,000               | 25.7     | 1,000(2)            | 21.7     | 500(2)           | 9.8      | 2,500 | 18.3     |
| 5th    | B, C & D(3)            | 1,003               | 23.5**   | 1,000               | 23.1     | 500              | 9.2      | 2,503 | 17.6     |
| 6th    | B(4), C(5)<br>D & E(6) | 1,000               | 25.7     | 1,000               | 21.7     | 500              | 9.9      | 2,500 | 18.5     |
| 7th    | D & E                  | 1,006               | 26.1     | 1,000               | 23.4     | 500              | 9.7      | 2,506 | 18.8     |

- (1) B group tires accomplished 476 miles of cross-country due to tire failures.
- (2) B group tires accomplished 524 miles of cross-country and 1,002 miles of secondary.
- (3) D group replaced A group at start of this period due to worn smooth condition of A group.
- (4) B group terminated during this period—replaced with E group. B group accomplished 358 miles pavement, 260 miles secondary and 161 miles of cross-country for a total of 779 miles.
- (5) C group due to ride and lone study accomplished 1,015 miles pavement, 1,000 miles secondary and 500 miles cross-country for a total of 2,515 miles this period.
- (6) E group, which replaced B group, started test in the middle of 6th period and finished in the middle of 7th period. This group accomplished 1,013 miles pavement, 1,026 miles secondary and 502 miles cross-country for a total of 2,541 miles.
- \* Average speed reduced; 1/2 speed, 21 hours break-in of replacement B group.
- \*\* Average speed reduced; 1/2 speed, 16 hours break-in of new D group tires.

TEST PROGRAM (Contd.)

Test Mileage (Contd.)

The following table indicates the test miles accumulated by each tire under each of the three conditions.

| <u>Tire Code</u> | <u>Highway Pave Miles</u> | <u>% of Total Miles</u> | <u>Secondary Gravel Miles</u> | <u>% of Total Miles</u> | <u>Cross-Country Miles</u> | <u>% of Total Miles</u> | <u>Total Miles</u> |
|------------------|---------------------------|-------------------------|-------------------------------|-------------------------|----------------------------|-------------------------|--------------------|
| A-1              | 4,000                     | 40                      | 4,002                         | 40                      | 2,020                      | 20                      | 10,022             |
| A-2              | 4,000                     | 40                      | 4,002                         | 40                      | 2,020                      | 20                      | 10,022             |
| A-3              | 4,000                     | 40                      | 4,002                         | 40                      | 2,020                      | 20                      | 10,022             |
| A-4              | 4,000                     | 40                      | 4,002                         | 40                      | 2,020                      | 20                      | 10,022             |
| B-1              | 3,000                     | 41                      | 2,784                         | 39                      | 1,447                      | 20                      | 7,231              |
| B-2              | 4,406                     | 40                      | 4,342                         | 40                      | 2,128                      | 20                      | 10,876             |
| B-3              | 2,374                     | 39                      | 2,539                         | 42                      | 1,184                      | 19                      | 6,097              |
| B-4              | 5,361                     | 40                      | 5,264                         | 40                      | 2,681                      | 20                      | 13,306             |
| B-5              | 2,987                     | 41                      | 2,725                         | 38                      | 1,497                      | 21                      | 7,209              |
| B-6              | 2,141                     | 39                      | 2,220                         | 40                      | 1,151                      | 21                      | 5,512              |
| B-7              | 955                       | 39                      | 922                           | 38                      | 553                        | 23                      | 2,430              |
| C-1              | 6,018                     | 40                      | 6,002                         | 40                      | 3,020                      | 20                      | 15,040             |
| C-2              | 6,018                     | 40                      | 6,002                         | 40                      | 3,020                      | 20                      | 15,040             |
| C-3              | 6,018                     | 40                      | 6,002                         | 40                      | 3,020                      | 20                      | 15,040             |
| C-4              | 6,018                     | 40                      | 6,002                         | 40                      | 3,020                      | 20                      | 15,040             |
| D-1              | 3,009                     | 40                      | 3,000                         | 40                      | 1,500                      | 20                      | 7,509              |
| D-2              | 3,009                     | 40                      | 3,000                         | 40                      | 1,500                      | 20                      | 7,509              |
| D-3              | 3,009                     | 40                      | 3,000                         | 40                      | 1,500                      | 20                      | 7,509              |
| D-4              | 3,009                     | 40                      | 3,000                         | 40                      | 1,500                      | 20                      | 7,509              |
| E-1              | 1,013                     | 40                      | 1,026                         | 40                      | 502                        | 20                      | 2,541              |
| E-2              | 1,013                     | 40                      | 1,026                         | 40                      | 502                        | 20                      | 2,541              |
| E-3              | 1,013                     | 40                      | 1,026                         | 40                      | 502                        | 20                      | 2,541              |
| E-4              | 1,013                     | 40                      | 1,026                         | 40                      | 502                        | 20                      | 2,541              |

# TEST PROGRAM (Contd.)

## Tire Contact Areas

Contact prints were made at start of test of the right front tire of each test group at 30 psig. Additional contact prints were taken on the Group A and B tires at 15, 20 and 40 psig inflation. The gross and net contact areas for each tire and the ratio of net to gross is tabulated below.

| Vehicle Number<br>Tire Code | 15    |       |  | 20    |       |  | 30    |       |       | 40    |     |       |
|-----------------------------|-------|-------|--|-------|-------|--|-------|-------|-------|-------|-----|-------|
|                             | C-1   | C-2   |  | C-1   | C-2   |  | C-1   | C-2   | C-3   | C-1   | C-2 | C-3   |
|                             | A-2   | B-2   |  | A-2   | B-2   |  | A-2   | B-2   | C-2   | A-2   | B-2 | C-2   |
| Gross Area, in <sup>2</sup> | 756.3 | 726.2 |  | 633.7 | 604.4 |  | 495.7 | 484.3 | 495.7 | 419.6 |     | 435.0 |
| Net Area, in <sup>2</sup>   | 269.2 | 404.8 |  | 253.4 | 377.9 |  | 192.3 | 284.4 | 192.3 | 156.9 |     | 255.5 |
| Ratio, Gross to Net         | 2.81  | 1.79  |  | 2.50  | 1.60  |  | 2.58  | 1.68  | 2.58  | 2.67  |     | 1.70  |
| Net % of Gross              | 35.5  | 55.7  |  | 40.0  | 62.5  |  | 38.8  | 59.4  | 38.8  | 37.4  |     | 58.7  |
| 101/Gross Area*             | 25.7  | 26.9  |  | 30.6  | 32.3  |  | 39.1  | 40.3  | 38.7  | 46.2  |     | 44.8  |
| 101/Net Area*               | 72.1  | 48.2  |  | 76.6  | 51.6  |  | 100.9 | 68.6  | 99.8  | 123.6 |     | 76.3  |

\* Based on R.F. weight, lbs.      A= 19,400      B= 19,500      C= 19,200

Group A:      Firestone Super Ground Grip Goer H.D., Control

Group B:      U.S. Royal Tactical M.S.

Group C:      Firestone Super Ground Grip Goer Directional

LOG CONTACT PRESSURE

29.5 25 COED TIDES

PROJECT 20-1-110

100

50

0

50

100

150

INFLATION, PSIG

GROUP A

DIRECTIONAL CONVENTIONAL

GROUP B

NON-DIRECTIONAL RADIAL

200

300

400

CONTACT AREA NET INCH<sup>2</sup>

11-1-83

11-1-83

11-1-83

## TEST PROGRAM (Contd.)

### Test Tire Measurements

The following measurements were taken and recorded prior to start and at every 2300-2500 miles of tire travel:

Outside Diameter

Shore Hardness - 3 places

Tread Depth - 6 places inside and outside

Tread Cutting (number and total length) minimum 2" length, 1/4" side-wall and to fabric in tread

Cross Section - 3 places

Contact Print - 30 psip on right front tire each group at start of test

### Tire Rotation

| <u>At End<br/>of<br/>Test Period</u> | <u>Tire<br/>Miles<br/>Accumulated</u> | <u>Rotation Schedule</u>                     | <u>Tire Groups<br/>Affected</u> |
|--------------------------------------|---------------------------------------|--|---------------------------------|
| #1                                   | 2,520                                 | Vehicle to vehicle-fixed wheel position.     | A, B, C                         |
| #2                                   | 2,502                                 | Diagonally front-to-rear-vehicle to vehicle. | A, B, C                         |
| #3                                   | 2,500                                 | Vehicle to vehicle-fixed wheel position.     | A, B, C                         |
| #4                                   | 2,500                                 | Vehicle to vehicle-fixed wheel position.     | B, C, D                         |
| #5                                   | 2,503                                 | Vehicle to vehicle-fixed wheel position.     | B, C, D                         |
| #6                                   | 2,500                                 | Vehicle to vehicle-fixed wheel position.     | D, E                            |
| #7                                   | 2,506                                 |  | Test Terminated                 |

### Additional Tests

Due to test termination prior to the 20,000 mile limit it was considered advisable to investigate two phenomena which occurred during the test. A noticeable difference in the "ride" characteristics between tire groups was found and an observed deficiency of the non-directional radial construction tires in shallow mud. These conditions were further investigated by means of instrumentation and are covered in Appendix A "Ride Study" and Appendix B "Shallow Mud Traction".

# SUMMARY OF FUEL CONSUMPTION BY TIRE GROUPS

## Group A Tires

|   | Gallons                  |                          | Total<br>Fuel |
|---|--------------------------|--------------------------|---------------|
|   | <u>Pavement<br/>Fuel</u> | <u>Off-Road<br/>Fuel</u> |               |
| 1st Period, 0-2520 Miles, Vehicle C-1     | 361.2                    | 782.3                    | 1143.5        |
| 2nd Period, 2520-5022 Miles, Vehicle C-3  | 370.2                    | 788.1                    | 1158.3        |
| 3rd Period, 5022-7522 Miles, Vehicle C-2  | 352.0                    | 791.6                    | 1143.6        |
| 4th Period, 7522-10022 Miles, Vehicle C-1 | 360.0                    | 723.9                    | 1083.9        |
| Total                                     | 1443.4                   | 3085.9                   | 4529.3        |
| Miles per Gallon                          | 2.77                     | 1.95                     | 2.21          |
| Rating                                    | 100                      | 100                      | 100           |

## Group B Tires

|  |        |        |        |
|--|--------|--------|--------|
| 1st Period, 0-2520 Miles, Vehicle C-2      | 371.8  | 728.9  | 1100.7 |
| 2nd Period, 2520-5022 Miles, Vehicle C-1   | 362.4  | 745.2  | 1107.6 |
| 3rd Period, 5022-7498 Miles, Vehicle C-3   | 332.2  | 707.3  | 1039.5 |
| 4th Period, 7498-10024 Miles, Vehicle C-2  | 329.2  | 726.3  | 1055.5 |
| 5th Period, 10024-12527 Miles, Vehicle C-1 | 336.0  | 655.1  | 991.1  |
| 6th Period, 12527-13306 Miles, Vehicle C-3 | 120.7  | 216.0  | 336.7  |
| Total                                      | 1852.3 | 3778.8 | 5631.1 |
| Miles per Gallon                           | 2.89   | 2.10   | 2.36   |
| Rating(1)                                  | 104    | 108    | 107    |

## Group C Tires

|  |        |        |        |
|--|--------|--------|--------|
| 1st Period, 0-2520 Miles, Vehicle C-3      | 377.9  | 787.8  | 1165.7 |
| 2nd Period, 2520-5022 Miles Vehicle C-2    | 390.9  | 813.9  | 1204.8 |
| 3rd Period, 5022-7522 Miles, Vehicle C-1   | 349.8  | 789.7  | 1139.5 |
| 4th Period, 7522-10022 Miles, Vehicle C-3  | 344.8  | 773.0  | 1117.8 |
| 5th Period, 10022-12525 Miles, Vehicle C-2 | 356.6  | 686.4  | 1043.0 |
| 6th Period, 12525-15040 Miles, Vehicle C-1 | 355.4  | 730.4  | 1085.8 |
| Total                                      | 2175.4 | 4581.2 | 6756.6 |
| Miles per Gallon                           | 2.77   | 1.97   | 2.23   |
| Rating(1)                                  | 100    | 101    | 101    |

(1) Ratings are based on the Group A (Control) average miles per gallon consumption during the four periods they ran.



SUMMARY OF FUEL CONSUMPTION BY TIRE GROUPS (Contd.)

Group D Tires

|  | Gallons                  |                          |                       |
|--|--------------------------|--------------------------|-----------------------|
|  | <u>Pavement<br/>Fuel</u> | <u>Off-Road<br/>Fuel</u> | <u>Total<br/>Fuel</u> |
| 5th Period, 0-2503 Miles, Vehicle C-3    | 352.0                    | 682.9                    | 1034.9                |
| 6th Period, 2503-5003 Miles, Vehicle C-2 | 318.2                    | 701.1                    | 1019.3                |
| 7th Period, 5003-7509 Miles, Vehicle C-1 | 334.7                    | 703.6                    | 1038.3                |
| Total                                    | 1004.9                   | 2087.6                   | 3092.5                |
| Miles Per Gallon                         | 2.99                     | 2.16                     | 2.43                  |
| Rating(1)                                | 108                      | 111                      | 110                   |

Group E Tires

|   |       |       |        |
|---|-------|-------|--------|
| 6th-7th Period, 0-2541 Miles, Vehicle C-3 | 333.5 | 739.9 | 1073.4 |
| Total                                     | 333.5 | 739.9 | 1073.4 |
| Miles per Gallon                          | 3.04  | 2.07  | 2.37   |
| Rating(1)                                 | 110   | 106   | 107    |

(1) Ratings are based on the Group A (Control) average miles per gallon consumption during the four periods they ran.

## VEHICLE DURABILITY

The three Model "C" Tournapulls used in this Tire Durability Test to simulate the Army Goer Vehicle experienced a minimal parts mortality record. Other than normal vehicle service and preventive maintenance the following table indicates all failures experienced during test.

| <u>Veh.<br/>#</u> | <u>Date</u> | <u>Mileage<br/>@<br/>Failure</u> | <u>Description<br/>of Failure</u>                                       | <u>Cause of Failure</u>  | <u>Disposition</u>   |
|-------------------|-------------|----------------------------------|---|--|--|
| C-1               | 3/11/63     | 4,799                            | Cable, Apron,<br>broken.  | Believed that apron<br>limit switch was<br>misaligned.                         | Replaced cable and<br>aligned limit<br>switch.   |
| C-1               | 4/5/63      | 8,431                            | Cab Bolt, right<br>front missing.                                       | Unknown.   | Replaced.  |
| C-1               | 5/17/63     | 10,725                           | DC charging rate<br>low.  | DC Rectifiers.   | Replaced.  |
| C-1               | 5/27/63     | 12,292                           | DC charging rate<br>low.  | Flux bridge not<br>property adjusted.  | Installed shims in<br>flux bridge.   |
| C-1               | 6/12/63     | 18,309                           | DC charging rate<br>low.  | Deficient coil in<br>transformer.  | Replaced trans-<br>former.   |
| C-2               | 4/5/63      | 8,431                            | Hose, Air Tank<br>Outlet, leaking.                                      | Ruptured.  | Replaced.  |
| C-2               | 6/4/63      | 16,341                           | Can Arm Ball Cap,<br>right, 2 cap screws<br>broken.                     | Unknown.   | Replaced.  |
| C-2               | 6/4/63      | 16,341                           | Wheel Studs, left<br>missing (Wheel came<br>off bending brake<br>drum). | Wheel Studs not<br>properly tightened.   | Replaced brake<br>drum, tapped wheel<br>stud holes and<br>replaced wheel stud                                  |
| C-2               | 6/8/63      | 17,609                           | Points, Steering<br>Relay, left, burn-<br>ed and not making<br>contact. | High resistance.   | Replaced left steer-<br>ing points. Note:<br>Points had been<br>dressed several times<br>prior to replacement. |
| C-3               | 3/30/63     | 7,522                            | Cable, Can Hoist,<br>flattened and<br>frayed.                           | Rubbing against can<br>sheave side plate<br>due to being laced<br>incorrectly. | Replaced cable and<br>laced correctly.   |
| C-3               | 4/2/63      | 7,777                            | Hose, Rear Brake,<br>main line broken at<br>brass fitting.              | Unknown.   | Replaced.  |

VEHICLE DURABILITY (Contd.)

| <u>Veh.<br/>#</u> | <u>Date</u> | <u>Mileage<br/>@<br/>Failure</u> | <u>Description<br/>of Failure</u>                                     | <u>Cause of Failure</u>   | <u>Disposition</u>   |
|-------------------|-------------|----------------------------------|---|---|--|
| C-3               | 4/5/63      | 8,517                            | Pin & Bearing,<br>Apron Sheave,<br>damaged.                           | Believed that apron<br>cable forced through<br>sheave while looped. | Replaced pin and<br>bearing. Welded<br>torn section of<br>sheave side cover.                                   |
| C-3               | 6/8/63      | 17,600                           | Points, Steering<br>Relay, left burned<br>and not making<br>contact.. | High resistance.  | Replaced left steer-<br>ing points. Note:<br>Points had been<br>dressed several times<br>prior to replacement. |

TEST DATA

1. TIME MEASUREMENT SUMMARY

Best Available Copy



| Miles. | Loss  | Miles/Mil | Moyn          |
|--------|-------|-----------|---------------|
| Per.   | Cum.  | Per.      | Per Cum Co.   |
| 46.50  |       |           |               |
| 8065   |       |           |               |
| 85     | 585   | 12.9      | 12.6 -        |
| 3361   |       |           |               |
| 704    | 1289  | 10.7      | 15.1 27.7     |
| 2141   |       |           |               |
| 1720   | 2509  | 6.1       | 9.0 26.3 54.0 |
|        | ✓ 340 | ✓ 29.5    | ✓ 22.7        |

②

# TIRE MEASUREMENT SUMMARY

HODGES TRANSPORTATION INC.

Form 128MS

Project 20-1-110 Tire Group A-2 Mfg. Descr. Firestone Super Ground Grip Goer H.D.

Control

Date Feb. 1963 Tire Size 29.5-25 P.R. 16 Ribs Lug Type Rotation Flg. X ea. 2500

psi 5000

| Pos. | Meas. | Miles | Lb/Gm | O.D.  | X     | Sec | Profile | Dur. | Orig. | Tread Depth |     |     |     | Tread Loss |     | Miles | Mils. & Loss |      | Miles/Mil | Worn       | Est      |
|------|-------|-------|-------|-------|-------|-----|---------|------|-------|-------------|-----|-----|-----|------------|-----|-------|--------------|------|-----------|------------|----------|
|      |       |       |       |       |       |     |         |      |       | V-1         | V-2 | V-3 | V-4 | V-5        | V-6 |       | Per.         | Cum. |           | Per Cum to |          |
| 2    | RF    | 2520  | 2520  | 74.15 | 30.51 |     | 57      | 1570 | 1500  | 1562        |     |     |     |            |     |       | 3139         |      |           |            |          |
|      | C-1   | 2520  | 2520  | 74.53 | 30.83 |     | 57      | 1387 | 1285  | 1136        |     |     |     |            |     |       | 2523         |      |           |            |          |
|      |       |       |       | 0.5   | 1.0   |     |         | 0183 | 0215  | 0433        |     |     |     |            |     |       | 616          | 616  |           | 12%        |          |
|      | RF    | 2502  | 5022  | 74.57 | 30.87 |     | 58      | 1007 | 1213  | 0520        |     |     |     |            |     |       | 1535         |      |           |            |          |
|      | C-3   |       |       | 0.6   | 1.2   |     |         | 0380 | 0072  | 0608        |     |     |     |            |     |       | 288          | 1604 | 5.1       | 6.3        | 315 51.1 |
|      | LR    | 2500  | 1523  | 74.33 | 30.83 |     | 57      | 183  | 1141  | 269         |     |     |     |            |     |       | 432          |      |           |            |          |
|      | C-2   |       |       | 0.2   | 1.0   |     |         | 024  | 072   | 259         |     |     |     |            |     |       | 1053         | 2687 | 4.6       | 5.6        | 345 85.4 |
|      | LR    | 2500  | 10022 | 74.19 | 30.86 |     | 57      | WA   | 890   | WA          |     |     |     |            |     |       | -            | -    | -         | -          | -        |
|      | C-1   |       |       | 0.05  | 1.1   |     |         |      | 251   |             |     |     |     |            |     |       |              |      |           |            |          |

Voids 1,2,3

| Station | Loss<br>Cum. | Miles/Mil<br>Per. | Cum. | Worn<br>Est<br>Per Cum to |
|---------|--------------|-------------------|------|---------------------------|
| 1000    |              |                   |      |                           |
| 1010    |              |                   |      |                           |
| 1020    |              |                   |      |                           |
| 1030    | 8.21         | 9.1               | -    | 17.2                      |
| 1040    |              |                   |      |                           |
| 1050    | 18.21        | 7.1               | 8.0  | 22.8                      |
| 1060    |              |                   |      |                           |
| 1070    |              |                   |      |                           |
| 1080    |              |                   |      |                           |
| 1090    | 20.46        | 6.5               | 7.4  | 24.9                      |
| 1100    |              |                   |      |                           |
| 1110    |              |                   |      |                           |
| 1120    |              |                   |      |                           |
| 1130    |              |                   |      |                           |
| 1140    |              |                   |      |                           |
| 1150    |              |                   |      |                           |
| 1160    |              |                   |      |                           |
| 1170    |              |                   |      |                           |
| 1180    |              |                   |      |                           |
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| 1200    |              |                   |      |                           |
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| 3980    |              |                   |      |                           |
| 3990    |              |                   |      |                           |
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| 4010    |              |                   |      |                           |
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| 4140    |              |                   |      |                           |
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| 4160    |              |                   |      |                           |
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| 4270    |              |                   |      |                           |
| 4280    |              |                   |      |                           |
| 4290    |              |                   |      |                           |
| 4300    |              |                   |      |                           |
| 4310    |              |                   |      |                           |
| 4320    |              |                   |      |                           |
| 4330    |              |                   |      |                           |
| 4340    |              |                   |      |                           |
| 4350    |              |                   |      |                           |
| 4360    |              |                   |      |                           |
| 4370    |              |                   |      |                           |
| 4380    |              |                   |      |                           |
| 4390    |              |                   |      |                           |
| 4400    |              |                   |      |                           |
| 4410    |              |                   |      |                           |
| 4420    |              |                   |      |                           |
| 4430    |              |                   |      |                           |
| 4440    |              |                   |      |                           |
| 4450    |              |                   |      |                           |
| 4460    |              |                   |      |                           |
| 4470    |              |                   |      |                           |
| 4480    |              |                   |      |                           |
| 4490    |              |                   |      |                           |
| 4500    |              |                   |      |                           |
| 4510    |              |                   |      |                           |
| 4520    |              |                   |      |                           |
| 4530    |              |                   |      |                           |
| 4540    |              |                   |      |                           |
| 4550    |              |                   |      |                           |
| 4560    |              |                   |      |                           |
| 4570    |              |                   |      |                           |
| 4580    |              |                   |      |                           |
| 4590    |              |                   |      |                           |
| 4600    |              |                   |      |                           |
| 4610    |              |                   |      |                           |
| 4620    |              |                   |      |                           |
| 4630    |              |                   |      |                           |
| 4640    |              |                   |      |                           |
| 4650    |              |                   |      |                           |
| 4660    |              |                   |      |                           |
| 4670    |              |                   |      |                           |
| 4680    |              |                   |      |                           |
| 4690    |              |                   |      |                           |
| 4700    |              |                   |      |                           |
| 4710    |              |                   |      |                           |
| 4720    |              |                   |      |                           |
| 4730    |              |                   |      |                           |
| 4740    |              |                   |      |                           |
| 4750    |              |                   |      |                           |
| 4760    |              |                   |      |                           |
| 4770    |              |                   |      |                           |
| 4780    |              |                   |      |                           |
| 4790    |              |                   |      |                           |
| 4800    |              |                   |      |                           |
| 4810    |              |                   |      |                           |
| 4820    |              |                   |      |                           |
| 4830    |              |                   |      |                           |
| 4840    |              |                   |      |                           |
| 4850    |              |                   |      |                           |
| 4860    |              |                   |      |                           |
| 4870    |              |                   |      |                           |
| 4880    |              |                   |      |                           |
| 4890    |              |                   |      |                           |
| 4900    |              |                   |      |                           |
| 4910    |              |                   |      |                           |
| 4920    |              |                   |      |                           |
| 4930    |              |                   |      |                           |



TIRE MEASUREMENT SUMMARY

HODGES TRANSPORTATION INC.

Form 128HS

Project 20-1-110

Tire Group A-3

Mfg. Descr. Firestone Super Ground Grip

Control

Date Feb-

1963 Tire Size 29.5-25

P.R. 16

Rotation E.g. X 2500

Yards 1.3

psig

psig

Yards 1.3

| Pos.                                 | Road | Miles | Loss | Inc     | Sec   | Profile | Dur. | Orig. Tread Depth & Tread Loss |       |       |     | Miles/Mil Per. | Morn. Per Cum. to B. |     |     |
|--------------------------------------|------|-------|------|---------|-------|---------|------|--------------------------------|-------|-------|-----|----------------|----------------------|-----|-----|
|                                      |      |       |      |         |       |         |      | V-1                            | V-2   | V-3   | V-4 |                |                      | V-5 | V-6 |
| LR                                   | 2520 | 2520  |      | 74.11   | 30.79 |         | 57   | 1.563                          | 1.500 | 1.861 |     |                |                      |     |     |
| C-1                                  |      |       |      | 73.91   | 30.74 |         | 57   | 1.475                          | 1.399 | 1.065 |     |                |                      |     |     |
|                                      |      |       |      | -0.2    | -0.2  |         |      | 0.088                          | 0.101 | 0.496 |     |                |                      |     |     |
| LR                                   | 2502 | 5022  |      | 73.53   | 30.83 |         | 58   | 1.128                          | 1.249 | 0.250 |     |                |                      |     |     |
| C-3                                  |      |       |      | -0.1    | 0.1   |         |      | 0.347                          | 0.180 | 0.815 |     |                |                      |     |     |
| RF                                   | 2500 | 1527  |      | 74.25   | 31.07 |         | 55   | 475                            | 1046  | 0150  |     |                |                      |     |     |
| C-2                                  |      |       |      | 0.2     | 0.9   |         |      | 708                            | 703   | 2820  |     |                |                      |     |     |
| RF                                   | 2600 | 10022 |      | 74.07   | 31.16 |         | 56   | 070                            | 813   | WA    |     |                |                      |     |     |
| C-1                                  |      |       |      | -(0.08) | 1.2   |         |      | 358                            | 533   | -     |     |                |                      |     |     |
| Tread Loss of Crown Measurement Only |      |       |      |         |       |         |      |                                |       |       |     |                |                      |     |     |
| Tread on inside shoulder worn away   |      |       |      |         |       |         |      |                                |       |       |     |                |                      |     |     |



FC 128MS

Control

**Re**

ea. 1500  
ea. 5000

[illegible]

| Mils. & Loss | Miles/Day | Per. Cum. | Per. Cum. | Per. Cum. |
|--------------|-----------|-----------|-----------|-----------|
| 4610         |           |           |           |           |
| 3842         |           |           |           |           |
| 761          | 7.2       | 9.9       | -         | 16.5      |
| 2810         |           |           |           |           |
| 1032         | 18.00     | 7.2       | 8.4       | 23582.0   |
| 1999         |           |           |           |           |
| 811          | 2611      | 9.2       | 8.6       | 17456.4   |
| 1356         |           |           |           |           |
| 643          | 3264      | 11.7      | 9.2       | 13.9 70.6 |
|              | 1492      |           | 20.4      | 13.9      |

2







## Form 1041-SS

Medical M.S.

Veh. to Veh. ea. 2500

| Pos.   | Meas. Miles |       | Lb/Gal | 0 Dr  |       | X Sec | Profile | Dur. "A" | Drig. Tread |       | Depth |     | Tread Loss |     | Miles V-6 | Milg. & Loss |      | Miles/Mil Per. | Cum. | Horn Per Cum to Build | Est Mil. |
|--|-------------|-------|--------|-------|-------|-------|---------|----------|-------------|-------|-------|-----|------------|-----|-----------|--------------|------|----------------|------|-----------------------|----------|
|  | Per.        | Cum.  |        | Loss  | Inc   |       |         |          | Inc         | Inc   | V-1   | V-2 | V-3        | V-4 |           | V-5          | Per. |                |      |                       |          |
| RR   | 0-19        |       |        | 73.98 | 31.84 |       |         | 58       | 1.363       | 1.339 |       |     |            |     |           |              | 2702 |                |      |                       |          |
| C-2  | 2520        | 2620  |        | 73.80 | 31.84 |       |         | 54       | 1.306       | 1.245 |       |     |            |     |           |              | 2551 |                |      |                       |          |
| RR   | 2502        | 5022  |        | 73.70 | 32.00 | 0     |         | 56       | 1.222       | 0.094 |       |     |            |     |           |              | 2350 |                |      |                       |          |
| C-1  |             |       |        |       | 0.5   |       |         |          | 0.084       | 0.117 |       |     |            |     |           |              | 201  | 252            | 24.9 | 28.5                  | 7.4      |
| LF   | 2476        | 7498  |        | 73.45 | 32.35 | 1.6   |         | 56       | 1.164       | 1.047 |       |     |            |     |           |              | 2211 |                |      |                       |          |
| C-3  |             |       |        |       |       |       |         |          | 0.58        | 0.81  |       |     |            |     |           |              | 139  | 491            | 35.6 | 30.5                  | 5.1      |
| LF   | 2526        | 10024 |        | 73.55 | 32.27 |       |         | 56       | 1.126       | 0.99  |       |     |            |     |           |              | 2125 |                |      |                       |          |
| C-2  |             |       |        |       | 1.4   |       |         |          | 0.38        | 0.48  |       |     |            |     |           |              | 086  | 577            | 68.7 | 34.7                  | 3.2      |
| LF   | 2503        | 12527 |        | 73.58 | 32.02 | 0.6   |         | 56       | 1.058       | 0.88  |       |     |            |     |           |              | 1946 |                |      |                       |          |
| C-1  |             |       |        |       |       |       |         |          | 0.68        | 1.11  |       |     |            |     |           |              | 179  | 156            | 28.0 | 33.1                  | 6.6      |
| LF   | 779         | 13306 |        |       |       |       |         | 58       | 0.50        | 0.24  |       |     |            |     |           |              | +    | -              | -    | -                     | -        |
| C-1  |             |       |        |       |       |       |         |          | 1.08        | 0.64  |       |     |            |     |           |              | -    | -              | +    | -                     | -        |
| TEST TERMINATED                                |             |       |        |       |       |       |         |          |             |       |       |     |            |     |           |              |      |                |      |                       |          |
| 6/5/63   |             |       |        |       |       |       |         |          |             |       |       |     |            |     |           |              |      |                |      |                       |          |
| (1) MEASUREMENTS WERE TAKEN ON UNMOUNTED TIRES |             |       |        |       |       |       |         |          |             |       |       |     |            |     |           |              |      |                |      |                       |          |





[illegible]



Voids 12.2

| Miles<br>Sec. | Loss<br>Cum. | Miles/Mil<br>Per. Cum. | Horn<br>Per Cum |
|---------------|--------------|------------------------|-----------------|
| 40            |              |                        |                 |
| 41            |              |                        |                 |
| 42            | 115          | 18.3                   | 189             |
| 43            |              |                        |                 |
| 44            | 874          | 16.1                   | 17.1            |
| 45            |              |                        | 10.5            |
| 46            |              |                        | 189             |
| 47            |              |                        |                 |
| 48            | 1712         | 17.5                   | 15.3            |
| 49            |              |                        | 17.9            |
| 50            |              |                        | 318             |
| 51            |              |                        |                 |
| 52            | 2096         | 12.1                   | 14.3            |
| 53            |              |                        | 13.3            |
| 54            |              |                        | 452             |
| 55            |              |                        |                 |
| 56            | 27           | 11.4                   | 13.6            |
| 57            |              |                        | 14.2            |
| 58            |              |                        | 294             |
| 59            |              |                        |                 |
| 60            | 185          | 18.5                   | 14.5            |
| 61            |              |                        | WS              |
| 62            |              |                        | WS              |
| 63            |              |                        | WS              |
| 64            |              |                        | WS              |
| 65            |              |                        | WS              |
| 66            |              |                        | WS              |
| 67            |              |                        | WS              |
| 68            |              |                        | WS              |
| 69            |              |                        | WS              |
| 70            |              |                        | WS              |
| 71            |              |                        | WS              |
| 72            |              |                        | WS              |
| 73            |              |                        | WS              |
| 74            |              |                        | WS              |
| 75            |              |                        | WS              |
| 76            |              |                        | WS              |
| 77            |              |                        | WS              |
| 78            |              |                        | WS              |
| 79            |              |                        | WS              |
| 80            |              |                        | WS              |
| 81            |              |                        | WS              |
| 82            |              |                        | WS              |
| 83            |              |                        | WS              |
| 84            |              |                        | WS              |
| 85            |              |                        | WS              |
| 86            |              |                        | WS              |
| 87            |              |                        | WS              |
| 88            |              |                        | WS              |
| 89            |              |                        | WS              |
| 90            |              |                        | WS              |
| 91            |              |                        | WS              |
| 92            |              |                        | WS              |
| 93            |              |                        | WS              |
| 94            |              |                        | WS              |
| 95            |              |                        | WS              |
| 96            |              |                        | WS              |
| 97            |              |                        | WS              |
| 98            |              |                        | WS              |
| 99            |              |                        | WS              |
| 100           |              |                        | WS              |

## TIRE MEASUREMENT SUMMARY

HODGES TRANSPORTATION INC.

Form 128MS

Project 20-1-110 Tire Group C-3

Mfg. Descr. Firestone Super Ground Grip Goer

Date Feb 1963 Tire Size 29.5-25 P.R. 16

Ribs Lugs Type

paig

Rotation Voids 1.3

Veh. to veh. ea. 2500

Eig. X ea. 5000

| Code                   | Pos. | Meas.      | Miles     | Lb/Gal | 0 Dr  | K Sec | Profile | Sur. Orig. | Tread Depth |       |       | Miles | Miles & Loss | Miles/Mil | Worn | Est Mi.  |
|------------------------|------|------------|-----------|--------|-------|-------|---------|------------|-------------|-------|-------|-------|--------------|-----------|------|----------|
|                        |      |            |           |        |       |       |         |            | V-1         | V-2   | V-3   |       |              |           |      |          |
| C-3                    | LR   | Per. Orig. | Per. Cum. | Loss   | Inc   | Inc   | Low     | 60         | 1.565       | 1.500 | 1.570 |       | 3135         |           |      |          |
|                        | C-3  | 2520       | 2520      |        | 73.82 | 30.52 |         | 62         | 1.538       | 1.373 | 1.810 |       | 2848         |           |      |          |
| LR                     |      |            |           |        | 0.2   | 0.4   |         |            | 0.027       | 0.127 | 0.260 |       | 0.287        | 17.6      | 9.2  |          |
|                        | C-2  | 2502       | 5022      |        | 74.20 | 30.62 |         | 64         | 1.392       | 1.292 | 1.007 |       | 2399         |           |      |          |
| RF                     |      |            |           |        | 0.5   | 0.3   |         |            | 0.146       | 0.081 | 0.303 |       | 0.449        | 11.1      | 13.6 | 14.328.5 |
|                        | C-1  | 2500       | 7522      |        | 74.56 | 30.88 |         | 63         | 1.205       | 1.221 | 0.97  |       | 2107         |           |      |          |
| C-1                    |      |            |           |        | 1.0   | 1.2   |         |            | 1.87        | 0.71  | 1.10  |       | 2.97         | 14.8      | 14.6 | 9.5330   |
|                        | RF   | 2520       | 10022     |        | 74.52 | 30.88 |         | 64         | 0.97        | 1.093 | 0.31  |       | 1728         |           |      |          |
| C-3                    |      |            |           |        | 0.9   | 1.2   |         |            | 3.08        | 1.28  | 0.66  |       | 3.74         | 13.4      | 14.2 | 11.944.9 |
|                        | RF   | 2503       | 12525     |        | 74.33 | 30.92 |         | 64         | 5.87        | 1.023 | 0.99  |       | 1286         |           |      |          |
| C-2                    |      |            |           |        | 0.7   | 1.3   |         |            | 3.10        | 0.70  | 1.32  |       | 4.42         | 11.3      | 13.5 | 14.1530  |
|                        | RF   | 2515       | 15040     |        | 74.47 | 30.94 |         | 64         | 4.22        | 0.93  | 5.41  |       | 9.63         |           |      |          |
| C-1                    |      |            |           |        | 0.9   | 1.4   |         |            | 1.65        | 0.90  | 1.58  |       | 3.23         | 15.6      | 13.8 | 10.361.3 |
|                        |      |            |           |        |       |       |         |            |             |       |       |       |              |           |      |          |
| TEST TERMINATED 6-1-63 |      |            |           |        |       |       |         |            |             |       |       |       |              |           |      |          |

Outside X 29500-3

**Voids 1, 2, 3**

[illegible]

Form 1040-1

Mfg. Deser. U.S. Royal Tactical M.S.

Tire Group C-4

|      | Tire | Size | P.R. | Ribs | Lines | Type |
|------|------|------|------|------|-------|------|
| 1963 |      | 29.5 | -25  | 16   |       |      |

**Line Type**

Dg10

**Robertson**

veh. to veh. ca. 2500  
Flg X ca. 5000

[illegible]

| Voids 1,2,3  |           |           |           |
|--------------|-----------|-----------|-----------|
| Miles & Loss | Miles/Mil | Morn      |           |
| Per. Cum.    | Per. Cum. | Per. Cum. | Per. Cum. |
| 4660         |           |           |           |
| 4298         |           |           |           |
| 367          | 332       | 22.8      | 72        |
| 3757         |           |           |           |
| 541          | 813       | 13.9      | 17.8      |
| 3311         |           |           |           |
| 440          | 1318      | 17.0      | 17.7      |
| 2924         |           |           |           |
| 393          | 1706      | 19.1      | 17.6      |
| 2483         |           |           |           |
| 411          | 2147      | 17.0      | 17.5      |
| 2061         |           |           |           |
| 414          | 2561      | 18.2      | 17.6      |
|              |           |           | 89.553    |



[illegible][illegible][illegible]

**HODGES TRANSPORTATION INC.**

Form 128MS

Project 20-1-110 Tire Group F Mfg. Descr. \_\_\_\_\_

**Mr. Deacr.**

U.S. District  
Court

**Normal**

DESIGNED - RADIA

W.P.Y.C.

WPA 8-2-44  
NATIONAL ARCHIVES  
SERIALS SECTION  
FORM 1001

[illegible]

[illegible]



# TIME CONDITION & SUMMARY

HODGES TRANSPORTATION INC.

Form 128-C

Proj. # 20-1-110

Tire Group A-2

Mfr. Descrip. Firestone Super Ground Grip

Control

Date Feb. 1963

Tire Size 295-25

P.R. 16

Rotation

Vehicle 2500

Flux 44 4600

| Loc. Pos. Miles | Fold Cracks              | U | SL | S-T | T-B-T | Scuff | I-V      | T-S | F-V        | F-S | Other                        |
|-----------------|--------------------------|---|----|-----|-------|-------|----------|-----|------------|-----|------------------------------|
| 2 RF 2520       |                          |   |    |     |       |       | M Ins    |     | M Toe      |     |                              |
| C-1 2-26        |                          |   |    |     |       |       | Out      |     | Se Heel    |     |                              |
| 2624            |                          |   |    |     |       |       |          |     | In + Out   |     | M wipe In & Out shoulder     |
| 2-28            |                          |   |    |     |       |       |          |     |            |     |                              |
| RF 5022         |                          |   |    |     |       |       | M Out    |     | M Out      |     |                              |
| C-3 3-15        |                          |   |    |     |       |       | Se In    |     | Se In      |     |                              |
| LB 7572         | 1 1/4 x 1 1/2" TE 2 1/2" |   |    |     |       |       | M Crown  |     | Se In      |     | SE RUBBING OFF LUGS IN       |
| C-2 3-30        | ENTIRE AS G              |   |    |     |       |       |          |     |            |     | CRACKED & BROKEN AREA        |
| LR 10022        | 1 1/4 x 3/4 TF Yes       |   |    |     |       |       | M Heel   |     | Se In 2 in |     | TF Outside shoulder          |
| C-1 4-16        | 4" to inside of crown    |   |    |     |       |       | In crown |     |            |     | 5 1/2 x 2" thru 2 breakers   |
|                 |                          |   |    |     |       |       |          |     |            |     | 2 1/2 x 1 1/4 thru 1 breaker |
|                 |                          |   |    |     |       |       |          |     |            |     | 1 1/2 x 1 Fabric exposed     |
|                 |                          |   |    |     |       |       |          |     |            |     | Se wiping In & Out, Tie      |
|                 |                          |   |    |     |       |       |          |     |            |     | REMOVED FROM TEST            |
|                 |                          |   |    |     |       |       |          |     |            |     | DUE TO BOTH SHOULDERS        |
|                 |                          |   |    |     |       |       |          |     |            |     | WORN SMOOTH                  |

Fold B-Hib A-11 CO-Chunkout WA-Worn Any TP-To, MTP-Not to Fabric. V8-Very slight S-slight N-Noting Se-Severe. UT-Undertear  
 S-Side Lift ST-Side Tear SET-Side End Tear TBT-Tie Bar Tear IT-Irregular Wear TS-Tread Splice TW-Tear Wear FS-Flat Spot  
 H-Heel To Toe Vehicles = C-1, C-2, C-3. In=Inside Shoulder Out= Outside Shoulder

5-28-64

Control

**Notation. Veh. to Veh. ca 2500**

**FinX 24,5000**

[illegible]

NOTE: THE FOLLOWING TABLE DOES NOT INDICATE CHANGES IN THE

**W-Heel** W-heel  
**T-Tee** T-tee  
**Vehicles = C-1, C-2, C-3** Vehicles = C-1, C-2, C-3  
**In = Inside Shoulder Out = Outside Shoulder.** In = Inside Shoulder Out = Outside Shoulder.  
**S-Slips** S-slips  
**Lift ST-Slits Tear SET-Slits End Tear TST-Tie Bar Tear IW-Irregular Wear TB-Tread Splice FW-Fast Wear FS-Flat Spot** Lift ST-Slits Tear SET-Slits End Tear TST-Tie Bar Tear IW-Irregular Wear TB-Tread Splice FW-Fast Wear FS-Flat Spot  
**A-All CO-Chunkout WA-Worn Away TP-To, WTF-Mot To Fabric.** A-All CO-Chunkout WA-Worn Away TP-To, WTF-Mot To Fabric.  
**V8-Very Slight S-Slight M-Medium Se-Severe.** V8-Very Slight S-Slight M-Medium Se-Severe.  
**UT-Undertear** UT-Undertear

# TIME CONDITION & SUMMARY

MOOGES TRANSPORTATION INC.

Form # 128-C

Control

Firestone Super Ground Grip Goer H.D.

1953 Tire Size 29.5-25 P.R. 16

Ribs Lug Type

Notation Veh to Veh ea. 2500

Fig. X ea 2500

| Pos.     | Miles | Void Cracks | UT | SL | ST | TBT | Scuff | IW          | TS | FW       | FS | Other                |
|----------|-------|-------------|----|----|----|-----|-------|-------------|----|----------|----|----------------------|
| RR 2520  |       |             |    |    |    |     |       | M In +      |    | SA heel  |    |                      |
| C-1 2-26 |       |             |    |    |    |     |       | Out         |    | M Toe    |    |                      |
| 2624     |       |             |    |    |    |     |       |             |    | IN-OUT   |    | M Wipe In & Out      |
| 2-20     |       |             |    |    |    |     |       |             |    |          |    |                      |
| RR 5022  |       |             |    |    |    |     |       | Se In       |    | SA Heel  |    | M Wipe In - Out      |
| C-3 3-15 |       |             |    |    |    |     |       | & Out       |    | IN-OUT   |    |                      |
| LF 17522 |       |             |    |    |    |     |       | SE IN-OUT   |    | SE HEEL  |    | SE WIPING OF LUGS IN |
| C-2 3-30 |       |             |    |    |    |     |       | At shoulder |    | IN GRIND |    | CENTER GROOVED AREA  |
| LF 10022 |       |             |    |    |    |     |       | M across    |    | Se In &  |    | Se Wiping In & Out   |
| C-1 4-16 |       |             |    |    |    |     |       | tread       |    | out      |    | TIRE GROUP REMAINED  |
|          |       |             |    |    |    |     |       |             |    |          |    | FROM TEST DUE TO     |
|          |       |             |    |    |    |     |       |             |    |          |    | THREE OF THE FOUR    |
|          |       |             |    |    |    |     |       |             |    |          |    | TIRES WORN SMOOTH.   |

fold R-Rib A-All CO-Chalkout MA-Worn Away TP-To, WTP-Not To Fabric. VS-Very Slight S-Slight N-Medium Se-Severe. UT-Under-tear  
 S-Side Lift ST-Side Tear SST-Side End Tear TBT-Tie Bar Tear IW-Irregular Wear TS-Tread Splice FW-Fast Wear FS-Flat Spot  
 H=Heel T=Toe. Vehicles C-1, C-2, C-3 In= Inside Shoulder Out= Outside Shoulder.



# TIME CONDITION & SUPPLY

MOORE TRANSPORTATION INC.

Form # 128-C

Proj. # 20-1-110

Tire Group B-1

Mfr. Descr. U.S. Royal Tactical M.S.

1963 Tire Size 22.5-25 P.R. 16

Ribs 142

Type

Notation

Vel. to Veh. ea. 2500

Fig. X ea. 5000

Other

Two 1/2" & One 2"

circumferential side-

wall splice openings,

outer, above bead, NTF

90% Fold Splice opening

outside. Se. bend seat

chafing outside. One

chafed area 1 3/4" long

broken thru top ply and

separated toward tread

1 1/4"

TIRE FAILED AND REMOVED

FROM TEST DUE TO EXCESSIVE

AIR LEAK FROM 4 1/2" AREA

OF BROKEN CORDS AT TOP

OF FLIPPER AND UNDER

TRAILING WALK OF FLIPPER

TOWARDS BEAD FOR 1 1/2"

AND 1" UP. EXCESSIVE ALL

PLYS ON OUTSIDE OF

FLIPPER AND TOP PLYS

REMOVING OF FLIPPER

REMOVED. 90% OF THE

STRIP WORN THRU. SIX

AREAS OF SKULLING

SIDEWALL. THREE AREAS

OF 5/8" AREAS ABOVE

SIDEWALL TREADS.

Old B-Rib A-All CO-Chunkout WA-Mess Any TT-To, MT-Mot To Fabric. VS-Very Slight S-Slight M-Medium Se-Severe. UT-Undertear  
 Side Lift ST-Side Type ST-Side End from ST-Tile Bar Tear IV-Irregular Near TS-Tread Splice TS-Tread Near FS-Flat Spot  
 H=Heal TT=The Vehicles = C-1 C-2, C-3. In=Inside shoulder Out=outside shoulder.



# TIRE CONDITION & SUMMARY

MOORE TRANSPORTATION INC.

Form 128-C

Proj. # 20-1-110 Tire Group B-2 Mfr. Descrip. U.S. Royal Sapirol M-3, Rotation Ven. to Veh. eq 2500  
 Date Feb. 12/3 Tire Size 295-25 P.R. 16 Ribbed Type safe

| Pos. / Flies                  | Vald Cracks | UT | SL | ST | TBT | Scuff | IV        | TS                               | FV      | FS | Other                                 |
|-------------------------------|-------------|----|----|----|-----|-------|-----------|----------------------------------|---------|----|---------------------------------------|
| RF 2520                       |             |    |    |    |     |       |           |                                  | VS Heel |    | 1" 3 1/2" @ 4 1/2" circum.            |
| C-2 2-20                      |             |    |    |    |     |       |           |                                  | In      |    | side wall splice openings             |
|                               |             |    |    |    |     |       |           |                                  |         |    | outer, above bead, NTF                |
|                               |             |    |    |    |     |       |           |                                  |         |    | 1/2" circum. sidewall                 |
|                               |             |    |    |    |     |       |           |                                  |         |    | splice opening, inner                 |
|                               |             |    |    |    |     |       |           |                                  |         |    | above bead, NTF                       |
| RF 5022                       |             |    |    |    |     |       | S In.     | S out                            | VS Heel |    | Fold openings, outside                |
| C-1 3-15                      |             |    |    |    |     |       | VS out    |                                  | S in.   |    | 1-2" 1-6 1/4" 1-8 1/2"                |
|                               |             |    |    |    |     |       |           |                                  |         |    | F.O. inside 1-1/2" NTF                |
| LR 7020                       |             |    |    |    |     |       | S out     | S out                            | M in    |    | End openings, outside                 |
| C-3 3-20                      |             |    |    |    |     |       |           |                                  | 1/2 out |    | 1-1" 1-1 1/2" 1-8" 1-10" TP           |
|                               |             |    |    |    |     |       |           |                                  |         |    | F.O. inside 1-1/2" NTF                |
|                               |             |    |    |    |     |       |           |                                  |         |    | 1/4" X 3/8" RADIAL CRACK              |
|                               |             |    |    |    |     |       |           |                                  |         |    | IN OUTSIDE SIDEWALL TE.               |
|                               |             |    |    |    |     |       |           |                                  |         |    | ONE AREA OF SWELLING                  |
|                               |             |    |    |    |     |       |           |                                  |         |    | ON INSIDE SIDEWALL                    |
| LR 10024                      |             |    |    |    |     |       | S across  | M heel out                       |         |    | Radial cracks, inside sidewall        |
| C-2 4-15                      |             |    |    |    |     |       | Tread     | B heel in                        |         |    | 18" up from flange, 1 1/2" X 1 1/2"   |
|                               |             |    |    |    |     |       |           |                                  |         |    | three wire plies, cords exposed       |
|                               |             |    |    |    |     |       |           |                                  |         |    | 11" up from flange, 1" X 1/4"         |
|                               |             |    |    |    |     |       |           |                                  |         |    | 1/2 X 1/2, three wire plies           |
|                               |             |    |    |    |     |       |           |                                  |         |    | 12 1/2" up from flange, 1 1/2" X 1/2" |
|                               |             |    |    |    |     |       |           |                                  |         |    | three wire plies, cords exposed       |
|                               |             |    |    |    |     |       |           |                                  |         |    | cut 1 1/2 X 1/2 three wire plies      |
|                               |             |    |    |    |     |       |           |                                  |         |    | cords exposed                         |
|                               |             |    |    |    |     |       |           |                                  |         |    | Fold opening, inside 1 1/2"           |
|                               |             |    |    |    |     |       |           |                                  |         |    | Break above bead, 1" TP               |
|                               |             |    |    |    |     |       |           |                                  |         |    | Fold opening, outside                 |
|                               |             |    |    |    |     |       |           |                                  |         |    | 2 1/2 X 3/4, 2 1/2 X 1/4 TP           |
|                               |             |    |    |    |     |       |           |                                  |         |    | 1 X 1/2 NTF                           |
| Radial crack from flange base |             |    |    |    |     |       | 3/4" wide | w/3/8" cracks extending parallel |         |    |                                       |
| to flange                     |             |    |    |    |     |       |           |                                  |         |    |                                       |
| Radial crack 1 1/4 X 3/4 deep |             |    |    |    |     |       |           |                                  |         |    |                                       |
|                               |             |    |    |    |     |       |           |                                  |         |    |                                       |

id R-Rib A-All CO-Chamout M-More Any TP-To, RTT-Rot To Fabric. VS-Very Slight S-Slight N-Medium So-Severe. UT-Undercar  
 lipse Lift ST-Slope Tear SET-Side End Tear TBT-Tile Bar Tear IV-Irregular Near TS-Tread Splice FU-Fast Near FS-Flat Spot

u-Head Tz Tan Vehicles = C-1, C-2, C-3 In = Inside Shoulder, Out = Outside shoulder.

Continuation

TP-70, TST-Not To Fabric. V8-Very slight 3-slight 4-medium 50-60mm. 60-70mm. 70-80mm. 80-90mm. 90-100mm. 100-110mm. 110-120mm. 120-130mm. 130-140mm. 140-150mm. 150-160mm. 160-170mm. 170-180mm. 180-190mm. 190-200mm. 200-210mm. 210-220mm. 220-230mm. 230-240mm. 240-250mm. 250-260mm. 260-270mm. 270-280mm. 280-290mm. 290-300mm. 300-310mm. 310-320mm. 320-330mm. 330-340mm. 340-350mm. 350-360mm. 360-370mm. 370-380mm. 380-390mm. 390-400mm. 400-410mm. 410-420mm. 420-430mm. 430-440mm. 440-450mm. 450-460mm. 460-470mm. 470-480mm. 480-490mm. 490-500mm. 500-510mm. 510-520mm. 520-530mm. 530-540mm. 540-550mm. 550-560mm. 560-570mm. 570-580mm. 580-590mm. 590-600mm. 600-610mm. 610-620mm. 620-630mm. 630-640mm. 640-650mm. 650-660mm. 660-670mm. 670-680mm. 680-690mm. 690-700mm. 700-710mm. 710-720mm. 720-730mm. 730-740mm. 740-750mm. 750-760mm. 760-770mm. 770-780mm. 780-790mm. 790-800mm. 800-810mm. 810-820mm. 820-830mm. 830-840mm. 840-850mm. 850-860mm. 860-870mm. 870-880mm. 880-890mm. 890-900mm. 900-910mm. 910-920mm. 920-930mm. 930-940mm. 940-950mm. 950-960mm. 960-970mm. 970-980mm. 980-990mm. 990-1000mm. 1000-1010mm. 1010-1020mm. 1020-1030mm. 1030-1040mm. 1040-1050mm. 1050-1060mm. 1060-1070mm. 1070-1080mm. 1080-1090mm. 1090-1100mm. 1100-1110mm. 1110-1120mm. 1120-1130mm. 1130-1140mm. 1140-1150mm. 1150-1160mm. 1160-1170mm. 1170-1180mm. 1180-1190mm. 1190-1200mm. 1200-1210mm. 1210-1220mm. 1220-1230mm. 1230-1240mm. 1240-1250mm. 1250-1260mm. 1260-1270mm. 1270-1280mm. 1280-1290mm. 1290-1300mm. 1300-1310mm. 1310-1320mm. 1320-1330mm. 1330-1340mm. 1340-1350mm. 1350-1360mm. 1360-1370mm. 1370-1380mm. 1380-1390mm. 1390-1400mm. 1400-1410mm. 1410-1420mm. 1420-1430mm. 1430-1440mm. 1440-1450mm. 1450-1460mm. 1460-1470mm. 1470-1480mm. 1480-1490mm. 1490-1500mm. 1500-1510mm. 1510-1520mm. 1520-1530mm. 1530-1540mm. 1540-1550mm. 1550-1560mm. 1560-1570mm. 1570-1580mm. 1580-1590mm. 1590-1600mm. 1600-1610mm. 1610-1620mm. 1620-1630mm. 1630-1640mm. 1640-1650mm. 1650-1660mm. 1660-1670mm. 1670-1680mm. 1680-1690mm. 1690-1700mm. 1700-1710mm. 1710-1720mm. 1720-1730mm. 1730-1740mm. 1740-1750mm. 1750-1760mm. 1760-1770mm. 1770-1780mm. 1780-1790mm. 1790-1800mm. 1800-1810mm. 1810-1820mm. 1820-1830mm. 1830-1840mm. 1840-1850mm. 1850-1860mm. 1860-1870mm. 1870-1880mm. 1880-1890mm. 1890-1900mm. 1900-1910mm. 1910-1920mm. 1920-1930mm. 1930-1940mm. 1940-1950mm. 1950-1960mm. 1960-1970mm. 1970-1980mm. 1980-1990mm. 1990-2000mm. 2000-2010mm. 2010-2020mm. 2020-2030mm. 2030-2040mm. 2040-2050mm. 2050-2060mm. 2060-2070mm. 2070-2080mm. 2080-2090mm. 2090-2100mm. 2100-2110mm. 2110-2120mm. 2120-2130mm. 2130-2140mm. 2140-2150mm. 2150-2160mm. 2160-2170mm. 2170-2180mm. 2180-2190mm. 2190-2200mm. 2200-2210mm. 2210-2220mm. 2220-2230mm. 2230-2240mm. 2240-2250mm. 2250-2260mm. 2260-2270mm. 2270-2280mm. 2280-2290mm. 2290-2300mm. 2300-2310mm. 2310-2320mm. 2320-2330mm. 2330-2340mm. 2340-2350mm. 2350-2360mm. 2360-2370mm. 2370-2380mm. 2380-2390mm. 2390-2400mm. 2400-2410mm. 2410-2420mm. 2420-2430mm. 2430-2440mm. 2440-2450mm. 2450-2460mm. 2460-2470mm. 2470-2480mm. 2480-2490mm. 2490-2500mm. 2500-2510mm. 2510-2520mm. 2520-2530mm. 2530-2540mm. 2540-2550mm. 2550-2560mm. 2560-2570mm. 2570-2580mm. 2580-2590mm. 2590-2600mm. 2600-2610mm. 2610-2620mm. 2620-2630mm. 2630-2640mm. 2640-2650mm. 2650-2660mm. 2660-2670mm. 2670-2680mm. 2680-2690mm. 2690-2700mm. 2700-2710mm. 2710-2720mm. 2720-2730mm. 2730-2740mm. 2740-2750mm. 2750-2760mm. 2760-2770mm. 2770-2780mm. 2780-2790mm. 2790-2800mm. 2800-2810mm. 2810-2820mm. 2820-2830mm. 2830-2840mm. 2840-2850mm. 2850-2860mm. 2860-2870mm. 2870-2880mm. 2880-2890mm. 2890-2900mm. 2900-2910mm. 2910-2920mm. 2920-2930mm. 2930-2940mm. 2940-2950mm. 2950-2960mm. 2960-2970mm. 2970-2980mm. 2980-2990mm. 2990-3000mm. 3000-3010mm. 3010-3020mm. 3020-3030mm. 3030-3040mm. 3040-3050mm. 3050-3060mm. 3060-3070mm. 3070-3080mm. 3080-3090mm. 3090-3100mm. 3100-3110mm. 3110-3120mm. 3120-3130mm. 3130-3140mm. 3140-3150mm. 3150-3160mm. 3160-3170mm. 3170-3180mm. 3180-3190mm. 3190-3200mm. 3200-3210mm. 3210-3220mm. 3220-3230mm. 3230-3240mm. 3240-3250mm. 3250-3260mm. 3260-3270mm. 3270-3280mm. 3280-3290mm. 3290-3300mm. 3300-3310mm. 3310-3320mm. 3320-3330mm. 3330-3340mm. 3340-3350mm. 3350-3360mm. 3360-3370mm. 3370-3380mm. 3380-3390mm. 3390-3400mm. 3400-3410mm. 3410-3420mm. 3420-3430mm. 3430-3440mm. 3440-3450mm. 3450-3460mm. 3460-3470mm. 3470-3480mm. 3480-3490mm. 3490-3500mm. 3500-3510mm. 3510-3520mm. 3520-3530mm. 3530-3540mm. 3540-3550mm. 3550-3560mm. 3560-3570mm. 3570-3580mm. 3580-3590mm. 3590-3600mm. 3600-36

For. 128-C

## Tactical MS.

-ugs Type

[illegible]

void R-Rib A-All CO-Chunkout WA-Worn Away TP-Toe, WTP-Not To Fabric. VS-Very Slight S-Slight M-Medium Se-Severe. UT-Undertear  
-Sipe Lift ST-Sipe Tear SET-Sipe End Tear TBT-Tie Bar Tear IW-Irregular Wear TB-Tread Splice FW-Fast Wear FS-Flat Spot  
H=Heel T=Toe Vehicles = C-1, C-2, C-3 In=Inside shoulder, Out=outside shoulder.

Practical M.S.

Practical M.S.

87ed

paid \_\_\_\_\_

| Pos. Miles | Vold Cracks | UT | SL | ST | TBT | Souff | IN | TS | FW        | FS | Other   |
|------------|-------------|----|----|----|-----|-------|----|----|-----------|----|---|
| RR 2520    |             |    |    |    |     |       |    |    | VS Heel   |    | Tread lug repairs noted.  |
| C-2 236    |             |    |    |    |     |       |    |    | in.       |    | 1-1/4", 1-1/2" circumferential tread splice opening, outer above bead NTF   |
|            |             |    |    |    |     |       |    |    |           |    | Several bulged areas inside & out. sidewall fold opening, defective repair.   |
| RR 5022    |             |    |    |    |     |       |    |    | M H in.   |    | 80% of fold splice open inside. Same as above outside.  |
| C-1 318    |             |    |    |    |     |       |    |    |           |    |   |
| LF 7498    |             |    |    |    |     |       |    |    | USA NTF   |    | Fold openings outside.  |
| C-3 320    |             |    |    |    |     |       |    |    | S. H. and |    | 2-1/2" x 3/8" NTF, 1-2" x 1/2" NTF, 1-2" x 1/2" TE & 1-3" x 1/2" TP. 6 tread lug repairs visible. Flange flap on inside chafing off. Flange scuffing inside above bead. |
|            |             |    |    |    |     |       |    |    |           |    | Total circumference, tread above sidewall and on inside sidewall and tread areas on outside sidewall approx. 1/2" larger than normal. Sidewall profile.                 |
| LF 10026   |             |    |    |    |     |       |    |    | M to S    |    | Lug repair cracked at base  |
| C-2 416    |             |    |    |    |     |       |    |    | heel in   |    | 2 3/4 x 1/2. Chaffer strip lifting entire circumference, inside. Chafing in area.   |

id R-Rib A-All CO-Chamhove Wt-Worn Away TP-To, Wrt-Wrt to Fabric. V8-Very Slight S-Slight M-Medium Se-Severe. UT-Underwear  
 ipe Lfr ST-Slip Toe SRT-Slip End Toe TST-Tile Bar Toe IR-Irregular Wear T8-Tread Splice PU-Fast Wear F8-Flat Spot  
 W=Heel T+Toe Vehicles = C-1, C-2, C-3 In=inside shoulder, Out=outside shoulder

Form 1285

**Section**

[illegible]

-Fold R-Rib A-All CO-Chunkout WA-Worn Away TP-To, NTP-Not To Fabric. VS-Very Slight S-Slight M-Medium Se-Severe. UT-Undertear  
 -S-Slice Lift ST-Slice Tear SET-Slice End Tear TBT-Tie Bar Tear IV-Irregular Wear T8-Tread Splice FW-Fast Wear F8-Flat Spot

# TIRE CONDITION & SUMMARY

MOORE TRANSPORTATION INC.

Form # 120-C

Proj # 2001-145, Date 10/20/01, Tire Group 3-E, Hgr. Descrip. M.S. Rival Tactical M.S., Rotation Yes to No, 25000 Miles, Mileage 25000, P.R. 10, Ribbed Lug, Type 1018

| Pos. | Miles | Void Cracks | UT | SL | ST | TBT | Scuff | IV | TS | FH | FS | Other                         |
|------|-------|-------------|----|----|----|-----|-------|----|----|----|----|-------------------------------|
| 5 RF | 1401  |             |    |    |    |     |       |    |    |    |    | 1" Radial Crack TP            |
| C-3  | 3-30  |             |    |    |    |     |       |    |    |    |    | DEEP INSIDE SCUFFS            |
|      |       |             |    |    |    |     |       |    |    |    |    | AT FLANGE ABOVE RIBS          |
| RF   | 3927  |             |    |    |    |     |       |    |    |    |    | Radial crack 1/2" x 3/4" deep |
| C-2  | 4-16  |             |    |    |    |     |       |    |    |    |    | some at above                 |
| RF   | 6430  |             |    |    |    |     |       |    |    |    |    | 1" RADIAL CRACK TP            |
| C-1  | 5-29  |             |    |    |    |     |       |    |    |    |    | INSIDE SCUFFS                 |
|      |       |             |    |    |    |     |       |    |    |    |    | 3 bulges in S.W.              |
|      |       |             |    |    |    |     |       |    |    |    |    | 2 " OUT S.W.                  |
| RF   | 7209  |             |    |    |    |     |       |    |    |    |    | 1" RADIAL CRACK TP            |
| C-3  | 6-5   |             |    |    |    |     |       |    |    |    |    | INSIDE SCUFFS                 |
|      |       |             |    |    |    |     |       |    |    |    |    | BULGES UNCHANGED              |
|      |       |             |    |    |    |     |       |    |    |    |    | SL. BRAD CHAF IN-OUT          |
|      |       |             |    |    |    |     |       |    |    |    |    | STEEL WIRE SNDS               |
|      |       |             |    |    |    |     |       |    |    |    |    | STICKING OUT OF               |
|      |       |             |    |    |    |     |       |    |    |    |    | IN S.W. TWO                   |
|      |       |             |    |    |    |     |       |    |    |    |    | PATCH REPAIRS                 |
|      |       |             |    |    |    |     |       |    |    |    |    | COARSE BRANDED                |
|      |       |             |    |    |    |     |       |    |    |    |    | IN LINES                      |

Void R-Rib A-All CO-Chemout WA-Worn Away TP-To, NTF-Not To Fabric. V8-Very Slight 8-Slight N-Medium Se-Severe. UT-Undercut

S-Side Lift ST-Side Tear SET-Side End Tear TBT-Tie Bar Tear TBT-Tie Bar Tear IV-Irregular Wear TS-Tread Splice FH-Fast Wear FS-Flat Spot

H=Heal T=Toe V=Void C-1, C-2, C-3 IN=INSIDE SHOULDER OUT=OUTSIDE SHOULDER



1004 5-15-57

1

**Notation.**  $\mathbb{N}$ ,  $\mathbb{Z}$ ,  $\mathbb{R}$ ,  $\mathbb{C}$

[illegible]

VOID R-RIB A-ALL CO-CHUNKOUT WA-WORN AWAY TP-TO, WTF-NOT TO FABRIC. V8-VERY SLIGHT S-SLIGHT N-MEDIUM S8-SEVERE. UT-UNDERTEAR Y-SIDE LIFT ST-SIDE TEAR SET-SIDE END TEAR TBT-TILE BAR TEAR IV-IRREGULAR WEAR T8-TREAD SPLICE FW-FAST WEAR F8-FLAT SPOT

H=HEEL T=TOE V=VEHICLES=C-1,C-2,C-3  
IN=INSIDE SHOULDER OUT=OUTSIDE SHOULDER

42

1

**Notations**  $\mathcal{V}$  set of vertices,  $\mathcal{E}$  set of edges

[illegible]

VOID R-RIB A-ALL CO-CHUNKOUT WA-WORN AWAY TP-TO, WTP-NOT TO FABRIC. V3-VERY SLIGHT S-SLIGHT M-MEDIUM SO-SEVERE. UT-UNDERTEAR.  
S-SLIP LIFT ST-SLIP TEAR SET-SLIP END TEAR TBT-TIE BAR TEAR IV-IRREGULAR WEAR T3-TREAD SPLICE F4-FAST WEAR F3-FLAT SPOT  
H=HEEL T=TOE VEHICLES = C-1, C-2, C-3. IN=INSIDE SHOULDER, OUT=OUTSIDE SHOULDER.



# TIME CONDITION & SUMMARY

MODES TRANSPORTATION INC.

Form # 128-C

Proj. # 20-1-110 Tire Group C-2 Mfr. Descrip. Firestone Super Ground Grip Gser.  
 Date Feb. 1973 Tire Size 22.5-25 P.R. 16 Ribs Lugs Type psig. Rotation Veh. to Veh. ca 2500  
 Fig X ca 5000

| do  | Pos. | Miles | Vold Cracks         | UT         | SL | ST | TBT | Scuff | IW              | TS | PW         | FS | Other                   |
|-----|------|-------|---------------------|------------|----|----|-----|-------|-----------------|----|------------|----|-------------------------|
| P-2 | RF   | 2520  | 1 3/4" x 1 1/2"     | Yes @ base |    |    |     |       |                 |    | M heel out |    | S wipe in. M wipe out.  |
|     | C-3  | 2-26  |                     | center lug |    |    |     |       |                 |    | S heel in  |    | V5 ribbon delamination  |
|     | RF   | 5022  | 5" TF               | Yes        |    |    |     |       | M in &          |    |            |    | S wipe in. M wipe out.  |
|     | C-2  | 3-13  | 6" TF               | Yes        |    |    |     |       | Out             |    |            |    | V5 ribbon delamination  |
|     | RF   | 5022  | 5" TF               | Yes        |    |    |     |       | M in & out      |    |            |    | V5 ribbon delamination  |
|     | C-2  | 3-15  | 6" TF               | Yes        |    |    |     |       |                 |    | S Tag      |    | V5 ribbon delamination  |
|     |      |       |                     |            |    |    |     |       |                 |    | M heel     |    |                         |
|     |      |       |                     |            |    |    |     |       |                 |    | In & out   |    |                         |
|     | LR   | 7522  | 7" TF               | Yes 1 1/2" |    |    |     |       | M in-out        |    | M H in     |    | S WIPING IN & M WIPING  |
|     | C-1  | 2-30  | 7 1/4" TF           | Yes 1 1/2" |    |    |     |       | S in            |    | SE H out   |    | OUT AT CENTER GROOVE    |
|     |      |       |                     |            |    |    |     |       | turning         |    | S H out    |    | ARMA. S RIBBON DELAMIN. |
|     |      |       |                     |            |    |    |     |       |                 |    |            |    | TION.                   |
|     | LR   | 10022 | 8 1/4 x 1/2 TF      | Yes 1 3/4  |    |    |     |       | M across        |    | Se out     |    | SI ribbon delamination  |
|     | C-3  | 4-16  | 7 3/4 x 1/2 Thru    | Yes 1 3/4  |    |    |     |       | tire            |    | M in       |    | Se wipe in & out        |
|     |      |       | top breaker         |            |    |    |     |       |                 |    | SI crown   |    | Cut 3 x 3/8 NTF         |
|     |      |       | 4 1/2 x 1/8 TF      | Yes 1/4    |    |    |     |       |                 |    |            |    |                         |
|     | LR   | 12525 | 9 1/4 x 2 1/2" Thru | Yes 1 1/4  |    |    |     |       |                 |    |            |    |                         |
|     | C-2  | 5-29  | 9 1/2 x 2 1/2"      | "          |    |    |     |       | Two PILES       |    |            |    | SAME                    |
|     |      |       | 7 1/2 x 1 1/2"      | "          |    |    |     |       |                 |    |            |    |                         |
|     |      |       | 5 1/4 x 1 1/4       | "          |    |    |     |       |                 |    |            |    |                         |
|     |      |       | 2 3/4 x 3/4 TF      |            |    |    |     |       |                 |    |            |    |                         |
|     |      |       | 2 3/4 x 3/4 TF      |            |    |    |     |       |                 |    |            |    |                         |
|     | LR   | 15040 | 10" x 3 1/4"        | Yes        |    |    |     |       | Then FOUR PILES |    | Sev. wear  |    | Se. Wipe in & out       |
|     | C-1  | 6-11  | 12" x 4"            | Yes        |    |    |     |       | " SIX PILES     |    | Wear in    |    | SI ribbon delamin.      |
|     |      |       | 9" x 1 3/4"         | Yes        |    |    |     |       | " TWO PILES     |    | Crown      |    | CROWN LUGS TEARING      |
|     |      |       | 5" x 1"             | Yes        |    |    |     |       | " ONE PILE      |    |            |    | AT PRESSURE FRINT       |
|     |      |       | 3 1/2" x 3/4 TF     | Yes        |    |    |     |       |                 |    |            |    | BEAD O.K. LINES O.K.    |
|     |      |       | 5 1/2" x 1 1/2"     | Yes        |    |    |     |       | Then ONE PLY    |    |            |    | TIRE REMOVED FROM TIRE  |
|     |      |       | 2 1/2" x 1 1/4 NTF  | NO         |    |    |     |       |                 |    |            |    | DUE TO OUTSIDE SHOULD   |
|     |      |       |                     |            |    |    |     |       |                 |    |            |    | WHEEL SMOOTH.           |

Vold R-Rib A-All CO-Chamout MA-More Any TP-To, NTF-Not To Fabric. V8-Very Slight S-Slight M-Medium Se-Severe. UT-Undercar  
 -Sipe Left ST-Sipe Tear ST-Sipe End Tear TBT-Tie Bar Tear IN-Irregular Wear TS-Tread Splice PU-Fast Wear FS-Flat Spot

Wz Wear T=Toe Vehicles = C-1, C-2, C-3. In= Inside Shoulder Out = outside shoulder.

**Rotation Veh. to Veh. ca. 2500**

**Fig. 8**

**H-Neck** - Neckline C-1 C-2 D-5 In - Inside Shoulder Out - Outside shoulder  
**Sleeve Lift** - Sleeve Top Edge Line Red Tear T8-T9 Tie Bar Tear IV-Irregular Wear T8-Tread Splice PU-Fast Wear P8-Flat Spot  
**R-Rib A-Sil** - All Components Ink-Mark Away TP-To, RTT-NOT To Fabric. V8-Vary Slight N-Medium Se-Severs. UT-Underwear  
**S-Side Lf** - Side Seam Edge Line Red Tear T8-T9 Tie Bar Tear IV-Irregular Wear T8-Tread Splice PU-Fast Wear P8-Flat Spot



1

100

[illegible]

Wold R-Rib A-All CO-Chunkout VA-Worn Away TF-To, WTF-Not To Fabrico. V8-Very Slight S-Slight M-Medium Se-Severe. UT-Undercar-  
-Side Lift ST-Sipe Tear SET-Sipe End Tear TBT-Tie Bar Tear IV-Irregular Wear TB-Tread Splice TV-Fast Wear TP-Flat Spot



# TIRE CONDITION & SUMMARY

ARMED TRANSPORTATION INC.

Form # 123-E

Proj. # 20-1-110  
Date FEB

Tire Group 5

Tire Size 29.5-25 P.R. 16

U.S. Directional Pattern - RADIAL DAY CONSTRUCTION

msg. 29.5-25 P.R. 16 Ribs Lug. Type

Location 29.5-25 P.R. 16

| Code | Pos. | Miles | Void Cracks | UT | SL | ST | TST | Scuff | IV | FS | FW     | FS | Other                     |
|------|------|-------|-------------|----|----|----|-----|-------|----|----|--------|----|---------------------------|
| 1-1  | -    | 0-16  |             |    |    |    |     |       |    |    | S-H-AU |    | USED TIRE. SLUG           |
|      |      | 6-4   |             |    |    |    |     |       |    |    | LUCA   |    | CHIPPING. 2 1/2" RADIAL   |
|      |      |       |             |    |    |    |     |       |    |    |        |    | CRACK 0.100" IN DEPTH     |
|      |      |       |             |    |    |    |     |       |    |    |        |    | NITE INSIDE SIDEWALL      |
|      |      |       |             |    |    |    |     |       |    |    |        |    | CIRCUMFERENTIAL FLAW      |
|      |      |       |             |    |    |    |     |       |    |    |        |    | CRACKS ABOVE BEAD         |
|      |      |       |             |    |    |    |     |       |    |    |        |    | CRACKS ABOVE BEAD         |
|      |      |       |             |    |    |    |     |       |    |    |        |    | SHALLOW CUTTING ON        |
|      |      |       |             |    |    |    |     |       |    |    |        |    | LUCA                      |
| LR   | 2041 |       |             |    |    |    |     |       |    |    | M-H-M  |    | 2 1/2" x 1/2" CUT IN VOID |
| C-3  | 6-18 |       |             |    |    |    |     |       |    |    | 1 CUT  |    | INSIDE. SHALLOW CUTTING   |
|      |      |       |             |    |    |    |     |       |    |    | S-H-M  |    | ON LUCA. 9 1/4" X 0.150"  |
|      |      |       |             |    |    |    |     |       |    |    |        |    | RADIAL CRACK SITE INSIDE  |
|      |      |       |             |    |    |    |     |       |    |    |        |    | SIDEWALL. 7 1/2" X 0.100" |
|      |      |       |             |    |    |    |     |       |    |    |        |    | RADIAL CRACK NITE INSIDE  |
|      |      |       |             |    |    |    |     |       |    |    |        |    | BEWALL. CIRCUMFERENTIAL   |
|      |      |       |             |    |    |    |     |       |    |    |        |    | FLAW CRACKS ABOVE BEAD    |
|      |      |       |             |    |    |    |     |       |    |    |        |    | OUTSIDE SIDEWALL          |
| -    | -    | 0-16  |             |    |    |    |     |       |    |    | S-H-AU |    | USED TIRE. HED LUG        |
|      |      | 6-4   |             |    |    |    |     |       |    |    | LUCA   |    | CHIPPING AND TEARING.     |
|      |      |       |             |    |    |    |     |       |    |    |        |    | SL CRACK CRACKING         |
|      |      |       |             |    |    |    |     |       |    |    |        |    | ACROSS TREAD. SL FLAW     |
|      |      |       |             |    |    |    |     |       |    |    |        |    | CRACKING ABOVE BEAD       |
|      |      |       |             |    |    |    |     |       |    |    |        |    | INSIDE SIDEWALL           |
| RR   | 2041 |       |             |    |    |    |     |       |    |    | SL H-M |    | MED LUG CHIPPING AND      |
| C-3  | 6-18 |       |             |    |    |    |     |       |    |    | M H IN |    | TEARING. 2 1/2" X 0.100"  |
|      |      |       |             |    |    |    |     |       |    |    | M H IN |    | RADIAL CRACK NITE         |
|      |      |       |             |    |    |    |     |       |    |    |        |    | INSIDE SHOULDER. SL FLAW  |
|      |      |       |             |    |    |    |     |       |    |    |        |    | CRACKING INSIDE & OUTSIDE |
|      |      |       |             |    |    |    |     |       |    |    |        |    | SIDEWALL. SL CRACK        |
|      |      |       |             |    |    |    |     |       |    |    |        |    | CRACKING ACROSS TREAD     |

Void R-Rib A-ALL CO-Chunkout UA-Worn Away TP-To, NTP-Not To Fabric. VS-Very Slight S-Slight M-Medium Se-Severe. UT-Undercarriage  
-Sipe Lift ST-Sipe Tear SST-Sipe End Tear TST-Tie Bar Tear IV-Irregular Wear TS-Tread Splice FW-Past Wear FS-Flat Spot





# Best Available Copy

## PLST DATA (Contd.)

### 3. Tread Temperature and Tire Pressures

Original Pavement Course Operation (10+ miles per shift)

| Tire Group | C       | D       |
|------------|---------|---------|
| Vehicle    | C-1     | C-2     |
| Date       | 2/27/63 | 2/27/63 |
| Miles      | 2773    | 2773    |
| Ambient    | 49°F    |         |
| Pavement   | --      |         |

|            | C     |           | D     |           |
|------------|-------|-----------|-------|-----------|
|            | Start | Temp. Inc | Start | Temp. Inc |
| LF         | --    | --        | --    | --        |
| RF         | --    | --        | --    | --        |
| Avg. Front | --    | --        | --    | --        |
| LP         | 25.0  | 33.0      | 25.0  | 36.0      |
| RR         | 25.0  | 33.0      | 25.0  | 36.0      |
| Avg. Rear  | 25.0  | 33.0      | 25.0  | 36.0      |
| Avg. Group | --    | --        | --    | --        |

|          |         |         |
|----------|---------|---------|
| Date     | 2/28/63 | 2/28/63 |
| Miles    | 2870    | 2870    |
| Ambient  | 50°F    |         |
| Pavement | 68°F    |         |

|            | C     |           | D     |           |
|------------|-------|-----------|-------|-----------|
|            | Start | Temp. Inc | Start | Temp. Inc |
| LF         | 36.0  | 47.0      | 36.0  | 47.0      |
| RF         | 36.0  | 47.0      | 36.0  | 47.0      |
| Avg. Front | 36.0  | 47.0      | 36.0  | 47.0      |
| LP         | 25.0  | 34.0      | 26.0  | 35.0      |
| RR         | 26.0  | 35.0      | 26.0  | 35.0      |
| Avg. Rear  | 26.0  | 35.0      | 26.0  | 35.0      |
| Avg. Group | 31.0  | 41.0      | 31.0  | 41.0      |



# TEST DATA (Contd.)

## 3. Tread Temperature and Tire Pressures (Contd.)

### Original Pavement Course Operation (104 miles per shift) (Contd.)

| Tire Group | A          |      |      | B         |      |     | C         |      |      |      |     |
|------------|------------|------|------|-----------|------|-----|-----------|------|------|------|-----|
|            | Start      | Temp | Inc  | Start     | Temp | Inc | Start     | Temp | Inc  |      |     |
| Vehicle    | C-3        |      |      | C-1       |      |     | C-2       |      |      |      |     |
| Date       | 3/1/63(1)  |      |      | 3/1/63(2) |      |     | 3/1/63(1) |      |      |      |     |
| Miles      | 3121       |      |      | 3121      |      |     | 3121      |      |      |      |     |
| Ambient    | 55°F       |      |      |           |      |     |           |      |      |      |     |
| Pavement   | 69°F       |      |      |           |      |     |           |      |      |      |     |
|            | LF         | A-1  | 36.0 | 51.0      | 15.0 | 177 | B-1       | 41.0 | 51.5 | 10.5 | 185 |
|            | RF         | A-2  | 36.0 | 51.5      | 15.5 | 175 | B-2       | 41.0 | 51.0 | 10.0 | 185 |
|            | Avg. Front |      | 36.0 | 51.5      | 15.5 | 176 |           | 41.0 | 51.5 | 10.5 | 185 |
|            | LR         | A-3  | 26.0 | 39.0      | 13.0 | 195 | B-3       | 26.0 | 35.0 | 9.0  | 165 |
|            | RR         | A-4  | 26.0 | 39.0      | 13.0 | 190 | B-4       | 26.0 | 37.0 | 11.0 | 165 |
|            | Avg. Rear  |      | 26.0 | 39.0      | 13.0 | 193 |           | 26.0 | 36.0 | 10.0 | 165 |
|            | Avg. Group |      | 31.0 | 45.0      | 14.0 | 184 |           | 34.0 | 44.0 | 10.0 | 175 |
| Date       | 3/8/63(1)  |      |      | 3/8/63(2) |      |     | 3/8/63(1) |      |      |      |     |
| Miles      | 4399       |      |      | 4399      |      |     | 4399      |      |      |      |     |
| Ambient    | 54°F       |      |      |           |      |     |           |      |      |      |     |
| Pavement   | 68°F       |      |      |           |      |     |           |      |      |      |     |
|            | LF         | A-1  | 35.0 | 47.5      | 12.5 | 190 | B-1       | 40.0 | 51.0 | 11.0 | 210 |
|            | RF         | A-2  | 35.0 | 49.0      | 14.0 | 183 | B-2       | 40.0 | 51.5 | 11.5 | 205 |
|            | Avg. Front |      | 35.0 | 48.0      | 13.0 | 187 |           | 40.0 | 51.5 | 11.5 | 208 |
|            | LR         | A-3  | 25.0 | 35.5      | 10.5 | 192 | B-3       | 25.0 | 34.0 | 9.0  | 174 |
|            | RR         | A-4  | 25.0 | 35.0      | 10.0 | 183 | B-4       | 25.0 | 37.0 | 12.0 | 160 |
|            | Avg. Rear  |      | 25.0 | 35.5      | 10.5 | 188 |           | 25.0 | 36.0 | 11.0 | 167 |
|            | Avg. Group |      | 30.0 | 42.0      | 12.0 | 187 |           | 32.5 | 43.5 | 11.0 | 187 |
|            | LF         |      |      |           |      |     |           | 40.0 | 54.0 | 14.0 | 185 |
|            | RF         |      |      |           |      |     |           | 40.0 | 54.5 | 14.5 | 192 |
|            | Avg. Front |      |      |           |      |     |           | 40.0 | 54.5 | 14.5 | 189 |
|            | LR         |      |      |           |      |     |           | 30.0 | 41.0 | 11.0 | 178 |
|            | RR         |      |      |           |      |     |           | 30.0 | 41.5 | 11.5 | 180 |
|            | Avg. Rear  |      |      |           |      |     |           | 30.0 | 41.5 | 11.5 | 179 |
|            | Avg. Group |      |      |           |      |     |           | 35.0 | 48.0 | 13.0 | 184 |

(1) Taken 9" from crown center.

(2) Taken 10 1/2" from crown center.

# TEST DATA (Contd.)

## 3. Tread Temperatures and Tire Pressures

### Revised Pavement Course Operation (194 miles per shift)

| Tire Group | A        |      |      | B         |      |      | C        |      |      |
|------------|----------|------|------|-----------|------|------|----------|------|------|
|            | Start    | Temp | Inc  | Start     | Temp | Inc  | Start    | Temp | Inc  |
| Vehicle    | C-2      |      |      | C-3       |      |      | C-1      |      |      |
| Date       | 3/19/63* |      |      | 3/19/63** |      |      | 3/19/63* |      |      |
| Miles      | 5611     |      |      | 5611      |      |      | 5611     |      |      |
| Ambient    | 60°F     |      |      |           |      |      |          |      |      |
| Pavement   | 78°F     |      |      |           |      |      |          |      |      |
| LF         | A-4      | 35.0 | 49.0 | B-4       | 40.0 | 50.5 | C-4      | 40.0 | 55.0 |
|            | A-3      | 35.0 | 50.0 | B-3       | 40.0 | 51.0 | C-3      | 40.0 | 55.0 |
| Avg. Front | A-2      | 35.0 | 49.5 | B-2       | 40.0 | 51.0 | C-2      | 40.0 | 55.0 |
|            | A-1      | 25.0 | 37.5 | B-1       | 25.0 | 35.0 | C-1      | 30.0 | 40.0 |
| Avg. Rear  | A-4      | 25.0 | 38.0 | B-4       | 25.0 | 34.5 | C-4      | 30.0 | 43.0 |
|            | A-3      | 25.0 | 38.0 | B-3       | 25.0 | 35.0 | C-3      | 30.0 | 41.5 |
| Avg. Group |          | 30.0 | 43.5 |           | 32.5 | 43.0 |          | 35.0 | 48.0 |
| Date       | 3/21/63* |      |      | 3/21/63** |      |      | 3/21/63* |      |      |
| Miles      | 6029     |      |      | 6029      |      |      | 6029     |      |      |
| Ambient    | 64°F     |      |      |           |      |      |          |      |      |
| Pavement   | 72°F     |      |      |           |      |      |          |      |      |
| LF         | A-4      | 35.0 | 50.0 | B-4       | 40.0 | 53.5 | C-4      | 41.0 | 58.0 |
|            | A-3      | 35.0 | 50.5 | B-3       | 40.0 | 52.5 | C-3      | 41.0 | 58.0 |
| Avg. Front | A-2      | 35.0 | 50.5 | B-2       | 40.0 | 53.0 | C-2      | 41.0 | 58.0 |
|            | A-1      | 26.0 | 38.5 | B-1       | 26.0 | 36.5 | C-1      | 31.0 | 44.0 |
| Avg. Rear  | A-4      | 26.0 | 37.0 | B-4       | 26.0 | 36.5 | C-4      | 31.0 | 46.0 |
|            | A-3      | 26.0 | 38.0 | B-3       | 26.0 | 36.5 | C-3      | 31.0 | 45.0 |
| Avg. Group |          | 30.5 | 44.0 |           | 33.0 | 44.5 |          | 36.0 | 51.5 |

(1) Tire had one area of 265°F.

(2) Tire had one separated tread area at 275°F. Tire was removed at end of shift.

\* Taken 9" from crown center.

\*\* Taken 10 1/2" from crown center.

### 3. Tread Temperatures and Tire Pressures (Contd.)

## Revised Pavement Course Operation (194 miles per shift) (Contd.)

| Tire Group | <u>A</u>   | <u>B</u>  | <u>C</u>   |
|------------|------------|-----------|------------|
| Vehicle    | C-2        | C-3       | C-1        |
| Date       | 3/25/63*** | 3/25/63** | 3/25/63*** |
| Miles      | 6408       | 6408      | 6408       |
| Ambient    | 57°F       |           |            |
| Pavement   | 70°F       |           |            |

|            |     | psig  |      |      | of  | Temp | psig  |      |      | of   | Temp |
|------------|-----|-------|------|------|-----|------|-------|------|------|------|------|
|            |     | Start | Temp | Inc  |     |      | Start | Temp | Inc  |      |      |
| LF         | A-4 | 35.0  | 48.5 | 13.5 | --  |      | B-4   | 40.0 | 53.0 | 13.0 | 175  |
| RF         | A-3 | 35.0  | 49.5 | 14.5 | 205 |      | B-5   | 40.0 | 52.0 | 12.0 | 180  |
| Avg. Front |     | 35.0  | --   | --   | --  |      |       | 40.0 | 52.5 | 12.5 | 178  |
| LR         | A-2 | 25.0  | 37.0 | 12.0 | --  |      | B-2   | 25.0 | 35.5 | 10.5 | --   |
| RR         | A-1 | 25.0  | 38.0 | 13.0 | --  |      | B-1   | 25.0 | 35.0 | 10.0 | --   |
| Avg. Rear  |     | --    | --   | --   | --  |      |       | 25.0 | 35.5 | 10.5 | --   |
| Avg. Group |     | --    | --   | --   | --  |      |       | --   | --   | --   | --   |
|            |     |       |      |      |     |      |       | 35.0 | 50.0 | 15.0 | --   |
|            |     |       |      |      |     |      |       | 40.0 | 56.0 | 16.0 | --   |
|            |     |       |      |      |     |      |       | 40.0 | 56.5 | 16.5 | 195  |
|            |     |       |      |      |     |      |       | 40.0 | 56.5 | 16.5 | --   |
|            |     |       |      |      |     |      |       | 30.0 | 42.5 | 12.5 | --   |
|            |     |       |      |      |     |      |       | 30.0 | 44.0 | 14.0 | --   |
|            |     |       |      |      |     |      |       | 30.0 | 50.0 | 13.5 | --   |
|            |     |       |      |      |     |      |       | 35.0 | 50.0 | 15.0 | --   |

| Date       | 3/26/63*** | 3/26/63** | 3/26/63*** |      |     |      |      |      |     |     |      |      |      |     |
|------------|------------|-----------|------------|------|-----|------|------|------|-----|-----|------|------|------|-----|
| Miles      | 6689       | 6689      | 6689       |      |     |      |      |      |     |     |      |      |      |     |
| Ambient    | 64°F       |           |            |      |     |      |      |      |     |     |      |      |      |     |
| Pavement   | 72°F       |           |            |      |     |      |      |      |     |     |      |      |      |     |
| LF         | A=4        | 35.0      | 50.0       | 15.0 | 210 | 40.0 | 53.0 | 13.0 | 199 | C=4 | 40.0 | 57.5 | 17.5 | 211 |
| RF         | A=3        | 35.0      | 51.0       | 16.5 | 222 | 40.0 | 52.0 | 12.0 | 190 | C=3 | 40.0 | 57.5 | 17.5 | 205 |
| Avg. Front |            | 35.0      | 50.5       | 15.5 | 216 | 40.0 | 52.5 | 12.5 | 195 |     | 40.0 | 57.5 | 17.5 | 208 |
| LR         | A=2        | 26.0      | 38.0       | 12.0 | 205 | 25.0 | 36.5 | 11.5 | 186 | C=2 | 30.0 | 37.5 | 7.5  | 199 |
| RR         | A=1        | 26.0      | 39.0       | 13.0 | 207 | 25.0 | 35.5 | 10.5 | 199 | C=1 | 30.0 | 38.5 | 8.5  | 199 |
| Avg. Rear  |            | 26.0      | 38.5       | 12.5 | 206 | 25.0 | 36.0 | 11.0 | 193 |     | 30.0 | 38.0 | 8.0  | 199 |
| Avg. Group |            | 30.5      | 44.5       | 14.0 | 211 | 32.5 | 44.0 | 11.5 | 194 |     | 35.0 | 48.0 | 13.0 | 204 |

\*\*\* Taken 10 1/2" from crown center.  
\*\*\* Taken 5 1/4" from crown center.

### 3. Tread Temperatures and Tire Pressures (Contd.)

## Revised Pavement Course Operation (194 miles per shift) (Contd.)

| Tire Group | A          |      | B         |      | C          |      |
|------------|------------|------|-----------|------|------------|------|
|            | Start      | Temp | Start     | Temp | Start      | Temp |
| Vehicle    | C-2        |      | C-3       |      | C-1        |      |
| Date       | 3/26/63*** |      | 3/26/63** |      | 3/26/63*** |      |
| Miles      | 6717       |      | 6731      |      | 6745       |      |
| Ambient    | 66°F       |      |           |      |            |      |
| Pavement   | 77°F       |      |           |      |            |      |

| Date       | Miles |
|------------|-------|
| 3/26/63**  | 6745  |
| Ambient    | 67°F  |
| Pavement   | 79°F  |
| LF         | B-4   |
| RF         | B-5   |
| Avg. Front |       |
| LR         | B-2   |
| RR         | B-1   |
| Avg. Rear  |       |

\*\*\* Taken 10 1/2" from crown center.

\*\*\* Taken 5 1/4" from crown center.

(1) Tire had one area of 230-237°f (suspected separation). The same area 14 miles later recorded a temperature of 237°f. No separation developed.

# TEST DATA (Contd.)

## 3. Tread Temperatures and Tire Pressures (Contd.)

### Secondary Road Operation

| Tire Group | A          |             |      |          | B         |             |      |            | C          |             |      |          |
|------------|------------|-------------|------|----------|-----------|-------------|------|------------|------------|-------------|------|----------|
|            | Start      | psig @ Temp | Inc  | of Temp  | Start     | psig @ Temp | Inc  | of Temp    | Start      | psig @ Temp | Inc  | of Temp  |
| Vehicle    | C-2        |             |      |          | C-3       |             |      |            | C-1        |             |      |          |
| Date       | 3/27/63*** |             |      |          | 3/27/63** |             |      |            | 3/27/63*** |             |      |          |
| Miles      | 6923       |             |      |          | 6923      |             |      |            | 6923       |             |      |          |
| Ambient    | 63°F       |             |      |          |           |             |      |            |            |             |      |          |
| Pavement   | (1)        |             |      |          |           |             |      |            |            |             |      |          |
| LF         | A-4        | 37.5        | 48.0 | 10.5 205 | B-4       | 42.0        | 52.5 | 10.5 190   | C-4        | 43.0        | 54.5 | 11.5 195 |
| RF         | A-3        | 37.5        | 47.5 | 10.0 202 | B-5       | 42.0        | 50.5 | 8.5 180    | C-3        | 43.0        | 54.5 | 11.5 195 |
| Avg. Front | A-2        | 37.5        | 48.0 | 10.5 204 |           | 42.0        | 51.5 | 9.5 185    |            | 43.0        | 54.5 | 11.5 195 |
| LR         | A-2        | 28.0        | 38.0 | 10.0 195 | B-2       | 27.5        | 35.0 | 7.5 180    | C-2        | 31.5        | 41.5 | 10.0 185 |
| RR         | A-1        | 28.0        | 37.5 | 9.5 195  | B-1       | 27.0        | 34.0 | 7.0 192(2) | C-1        | 31.5        | 42.0 | 10.5 180 |
| Avg. Rear  |            | 28.0        | 38.0 | 10.0 195 |           | 27.0        | 34.5 | 7.5 186    |            | 31.5        | 42.0 | 10.5 183 |
| Avg. Group |            | 33.0        | 43.0 | 10.0 199 |           | 34.5        | 43.0 | 8.5 186    |            | 37.0        | 48.0 | 11.0 189 |

(1) Temperature taken this day were of secondary operation.

(2) Tire had one tread area of 215°F.

\*\* Taken 10 1/2" from crown center.

\*\*\* Taken 5 1/4" from crown center.

# TEST DATA (Contd.)

## 3. Tread Temperatures and Tire Pressures (Contd.)

### Revised Pavement Course Operation (194 miles per shift) (Contd.)

| Tire Group    | A         |      |         | B        |      |         | C         |      |         |
|---------------|-----------|------|---------|----------|------|---------|-----------|------|---------|
|               | Start     | psig | of Temp | Start    | psig | of Temp | Start     | psig | of Temp |
| Vehicle       | C-1       |      |         | C-2      |      |         | C-3       |      |         |
| Date          | 4/4/63*** |      |         | 4/4/63** |      |         | 4/4/63*** |      |         |
| Miles to Date | 8106      |      |         | 8096     |      |         | 8135      |      |         |
| Ambient       | 60°F      |      |         | 60°F     |      |         |           |      |         |
| Pavement      | 70°F      |      |         | 75°F     |      |         |           |      |         |
| LF            | A-4       | 36.0 | 48.0    | 12.0     | 195  |         |           |      |         |
|               | A-3       | 36.0 | 50.0    | 14.0     | 202  |         |           |      |         |
| RF            | A-2       | 26.0 | 37.0    | 11.0     | 185  |         |           |      |         |
|               | A-1       | 26.0 | 37.0    | 11.0     | 185  |         |           |      |         |
| Avg. Front    | A-4       | 36.0 | 48.0    | 12.0     | 195  |         |           |      |         |
|               | A-3       | 36.0 | 50.0    | 14.0     | 202  |         |           |      |         |
| LR            | A-2       | 26.0 | 37.0    | 11.0     | 185  |         |           |      |         |
|               | A-1       | 26.0 | 37.0    | 11.0     | 185  |         |           |      |         |
| RR            | A-4       | 36.0 | 48.0    | 12.0     | 195  |         |           |      |         |
|               | A-3       | 36.0 | 50.0    | 14.0     | 202  |         |           |      |         |
| Avg. Rear     | A-2       | 26.0 | 37.0    | 11.0     | 185  |         |           |      |         |
|               | A-1       | 26.0 | 37.0    | 11.0     | 185  |         |           |      |         |
| Avg. Group    | A-4       | 36.0 | 48.0    | 12.0     | 195  |         |           |      |         |
|               | A-3       | 36.0 | 50.0    | 14.0     | 202  |         |           |      |         |
| LF            | A-4       | 36.0 | 48.0    | 12.0     | 195  |         |           |      |         |
|               | A-3       | 36.0 | 50.0    | 14.0     | 202  |         |           |      |         |
| RF            | A-2       | 26.0 | 37.0    | 11.0     | 185  |         |           |      |         |
|               | A-1       | 26.0 | 37.0    | 11.0     | 185  |         |           |      |         |
| Avg. Front    | A-4       | 36.0 | 48.0    | 12.0     | 195  |         |           |      |         |
|               | A-3       | 36.0 | 50.0    | 14.0     | 202  |         |           |      |         |
| LR            | A-2       | 26.0 | 37.0    | 11.0     | 185  |         |           |      |         |
|               | A-1       | 26.0 | 37.0    | 11.0     | 185  |         |           |      |         |
| RR            | A-4       | 36.0 | 48.0    | 12.0     | 195  |         |           |      |         |
|               | A-3       | 36.0 | 50.0    | 14.0     | 202  |         |           |      |         |
| Avg. Rear     | A-2       | 26.0 | 37.0    | 11.0     | 185  |         |           |      |         |
|               | A-1       | 26.0 | 37.0    | 11.0     | 185  |         |           |      |         |
| Avg. Group    | A-4       | 36.0 | 48.0    | 12.0     | 195  |         |           |      |         |
|               | A-3       | 36.0 | 50.0    | 14.0     | 202  |         |           |      |         |
| LF            | A-4       | 36.0 | 48.0    | 12.0     | 195  |         |           |      |         |
|               | A-3       | 36.0 | 50.0    | 14.0     | 202  |         |           |      |         |
| RF            | A-2       | 26.0 | 37.0    | 11.0     | 185  |         |           |      |         |
|               | A-1       | 26.0 | 37.0    | 11.0     | 185  |         |           |      |         |
| Avg. Front    | A-4       | 36.0 | 48.0    | 12.0     | 195  |         |           |      |         |
|               | A-3       | 36.0 | 50.0    | 14.0     | 202  |         |           |      |         |
| LR            | A-2       | 26.0 | 37.0    | 11.0     | 185  |         |           |      |         |
|               | A-1       | 26.0 | 37.0    | 11.0     | 185  |         |           |      |         |
| RR            | A-4       | 36.0 | 48.0    | 12.0     | 195  |         |           |      |         |
|               | A-3       | 36.0 | 50.0    | 14.0     | 202  |         |           |      |         |
| Avg. Rear     | A-2       | 26.0 | 37.0    | 11.0     | 185  |         |           |      |         |
|               | A-1       | 26.0 | 37.0    | 11.0     | 185  |         |           |      |         |
| Avg. Group    | A-4       | 36.0 | 48.0    | 12.0     | 195  |         |           |      |         |
|               | A-3       | 36.0 | 50.0    | 14.0     | 202  |         |           |      |         |

\*\* Taken 10 1/2" from crown center.

\*\*\* Taken 5 1/4" from crown center.

# TEST DATA (Contd.)

## 3. Tread Temperatures and Tire Pressures (Contd.)

### Revised Pavement Course Operation (194 miles per shift) (Contd.)

| Tire Group | A       |      |               | B       |          |      | C    |      |      |
|------------|---------|------|---------------|---------|----------|------|------|------|------|
|            | Vehicle | Date | Miles to Date | Ambient | Pavement | 52°F | 60°F | 70°F | 90°F |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |
|            |         |      |               |         |          |      |      |      |      |

\*\* Taken 10 1/2" from crown center.

\*\*\* Taken 5 1/4" from crown center.

### 3. Tread Temperatures and Tire Pressures (Contd.)

### Revised Pavement Course Operation (194 miles per shift) (Contd.)

|            |  | <u>psig</u>  |          |             | <u>of</u>    |          |             |
|------------|--|--------------|----------|-------------|--------------|----------|-------------|
|            |  | <u>Start</u> | <u>Q</u> | <u>Temp</u> | <u>Start</u> | <u>Q</u> | <u>Temp</u> |
| B-4        |  | 40.0         | 52.0     | 12.0        | 190          |          |             |
| B-5        |  | 40.0         | 51.0     | 11.0        | 185          |          |             |
| Avg. Front |  | --           | --       | --          | 188          |          |             |
| L.R.       |  | 25.0         | 36.5     | 11.5        | 200          |          |             |
| B-6        |  | 25.0         | 36.5     | 11.5        | 205(1)       |          |             |
| Avg. Rear  |  | --           | --       | --          | 203          |          |             |
| Avg. Group |  | --           | --       | --          | 195          |          |             |
| C-4        |  | 40.0         | 54.0     | 14.0        | 195          |          |             |
| C-3        |  | 40.0         | 55.0     | 15.0        | 200          |          |             |
| C-2        |  | 25.0         | 43.0     | 18.0        | 205          |          |             |
| C-1        |  | 25.0         | 45.0     | 20.0        | 195          |          |             |
| D-4        |  | 35.0         | 47.0     | 12.0        | 229          |          |             |
| D-3        |  | 35.0         | 48.0     | 13.0        | 234          |          |             |
| D-2        |  | 25.5         | 38.0     | 12.5        | 215          |          |             |
| D-1        |  | 26.0         | 38.0     | 12.0        | 210          |          |             |
| E-1        |  | --           | --       | --          | 213          |          |             |
| E-2        |  | --           | --       | --          | 222          |          |             |

|               |         |         |         |
|---------------|---------|---------|---------|
| Date          | 5/21/63 | 5/21/63 | 5/21/63 |
| Miles to Date | 10997   | 11072   | 1062    |
| Ambient       | 82°F    | 84°F    | 83°F    |
| Pavement      | 110°F   | 115°F   | 112°F   |

|            |     |      |      |      |     |     |      |      |      |     |     |      |      |      |     |
|------------|-----|------|------|------|-----|-----|------|------|------|-----|-----|------|------|------|-----|
| LF         | B-4 | 40.0 | 52.0 | 12.0 | 193 | C-4 | 40.0 | 55.0 | 15.0 | 220 | D-4 | 40.0 | 52.0 | 12.0 | 225 |
| RF         | B-5 | 40.0 | 50.5 | 10.5 | 193 | C-3 | 40.0 | 55.0 | 15.0 | 211 | D-3 | 40.0 | 52.0 | 12.0 | 225 |
| Avg. Front |     | --   | --   | --   | 193 |     | --   | --   | --   | 216 |     | --   | --   | --   | 225 |
| LR         | B-7 | 25.0 | 35.5 | 10.5 | 184 | C-2 | 30.0 | 41.0 | 11.0 | 240 | D-2 | 30.0 | 41.0 | 11.0 | 200 |
| RR         | B-6 | 25.0 | 36.0 | 11.0 | 265 | C-1 | 30.0 | 43.0 | 13.0 | 200 | D-1 | 30.0 | 42.0 | 12.0 | 205 |
| Avg. Rear  |     | --   | --   | --   | 225 |     | --   | --   | --   | 220 |     | --   | --   | --   | 203 |
| Avg. Group |     | --   | --   | --   | 209 |     | --   | --   | --   | 218 |     | --   | --   | --   | 214 |

(1) time had read sensation on inside shoulder which recorded a temperature of 255°F.



# TEST DATA (Contd.)

## 3. Tread Temperatures and Tire Pressures (Contd.)

### Revised Pavement Course Operation (194 miles per shift) (Contd.)

| Tire Group | B       |         |               | C       |          |  | D       |         |  |
|------------|---------|---------|---------------|---------|----------|--|---------|---------|--|
|            | Vehicle | Date    | Miles to Date | Ambient | Pavement |  | Vehicle | Date    |  |
|            | C-1     | 5/23/63 | 11466         | 71°F    | 83°F     |  | C-3     | 5/23/63 |  |
|            |         |         |               |         |          |  |         | 1603    |  |
|            |         |         |               |         |          |  |         | 65°F    |  |
|            |         |         |               |         |          |  |         | 79°F    |  |

|            | B     |      |             | C     |      |          | D     |      |          |
|------------|-------|------|-------------|-------|------|----------|-------|------|----------|
|            | Start | Q    | Temp        | Start | Q    | Temp     | Start | Q    | Temp     |
| LF         | 40.0  | 52.0 | 12.0 215    | 40.0  | 54.0 | 14.0 205 | 40.0  | 50.0 | 10.0 207 |
| RF         | 40.0  | 51.5 | 11.5 210    | 40.0  | 54.0 | 14.0 200 | 40.0  | 51.0 | 11.0 217 |
| Avg. Front | --    | --   | -- 213      | --    | --   | -- 203   | --    | --   | -- 212   |
| LR         | 25.0  | 36.0 | 11.0 200    | 30.0  | 40.0 | 10.0 225 | 30.0  | 40.0 | 10.0 195 |
| RR         | 25.0  | 36.5 | 11.5 265(I) | 30.0  | 40.0 | 10.0 210 | 30.0  | 40.5 | 10.5 193 |
| Avg. Rear  | --    | --   | -- 233      | --    | --   | -- 218   | --    | --   | -- 194   |
| Avg. Group | --    | --   | -- 223      | --    | --   | -- 210   | --    | --   | -- 203   |

(1) Tire separated around entire inside shoulder.

### 3. Tread Temperatures and Tire Pressures (Contd.)

Revised Pavement Course Operation (194 miles per shift.) (Contd.)

| Tire Group    | C      |      | D      |      | E      |      |
|---------------|--------|------|--------|------|--------|------|
|               | Start  | Temp | Start  | Temp | Start  | Temp |
| Vehicle       | C-1    |      | C-2    |      | C-3    |      |
| Date          | 6/6/63 |      | 6/6/63 |      | 6/6/63 |      |
| Miles to Date | 14189  |      | 3631   |      | 153    |      |
| Ambient       | 55°F   |      | 55°F   |      | 55°F   |      |
| Pavement      | 65°F   |      | 65°F   |      | 65°F   |      |

|    | C-4  | C-3  | C-2  | C-1 | psig  |      | of   |      | E-3 | E-4 | E-1 | E-2 | Avg. Front | Avg. Rear | Avg. Group |
|----|------|------|------|-----|-------|------|------|------|-----|-----|-----|-----|------------|-----------|------------|
|    |      |      |      |     | Start | Temp | Inc  | Temp |     |     |     |     |            |           |            |
| LF | 40.0 | 52.5 | 12.5 | 189 | D-4   | 40.0 | 50.0 | 10.0 | 212 |     |     |     |            |           |            |
| RF | 40.0 | 52.0 | 12.0 | 186 | D-3   | 40.0 | 49.5 | 9.5  | 206 |     |     |     |            |           |            |
|    | --   | --   | --   | 186 |       | --   | --   | --   | 209 |     |     |     |            |           |            |
|    | 30.0 | 39.5 | 9.5  | 200 | D-2   | 30.0 | 39.0 | 9.0  | 190 |     |     |     |            |           |            |
|    | 30.0 | 39.0 | 9.0  | 180 | D-1   | 30.0 | 39.0 | 9.0  | 195 |     |     |     |            |           |            |
|    | --   | --   | --   | 190 |       | --   | --   | --   | 193 |     |     |     |            |           |            |
|    | --   | --   | --   | 189 |       | --   | --   | --   | 201 |     |     |     |            |           |            |

# TEST DATA (Contd.)

## 3. Tread Temperatures and Tire Pressures (Contd.)

### Revised Pavement Course Operation (194 miles per shift) (Contd.)

Tire Group  
Vehicle  
Date  
Miles to Date  
Ambient 68°F  
Pavement 87°F

D  
C-2  
6/11/63  
4708  
E  
C-3  
6/11/63  
1199

|     | psig  |      |      | of  | psig  |      |      | of   |
|-----|-------|------|------|-----|-------|------|------|------|
|     | Start | Temp | Inc  |     | Start | Temp | Inc  |      |
| D-4 | 40.0  | 54.0 | 14.0 | 187 | E-3   | 40.0 | 52.5 | 12.5 |
| D-3 | 40.0  | 53.5 | 13.5 | 192 | E-4   | 40.0 | 52.0 | 12.0 |
|     | --    | --   | --   | 190 |       | --   | --   | --   |
| D-2 | 30.0  | 41.0 | 11.0 | 203 | E-1   | 30.0 | 38.0 | 8.0  |
| D-1 | 30.0  | 41.0 | 11.0 | 198 | E-2   | 30.0 | 39.5 | 9.5  |
|     | --    | --   | --   | 201 |       | --   | --   | --   |
|     | --    | --   | --   | 195 |       | --   | --   | --   |

Date  
Miles to Date  
Ambient 84°F  
Pavement 97°F

6/12/63  
1635

|     |      |      |      |     |     |      |      |      |     |
|-----|------|------|------|-----|-----|------|------|------|-----|
| D-4 | 40.0 | 56.0 | 16.0 | 216 | E-3 | 40.0 | 54.0 | 14.0 | 232 |
| D-3 | 40.0 | 55.0 | 15.0 | 212 | E-4 | 40.0 | 53.0 | 13.0 | 242 |
|     | --   | --   | --   | 214 |     | --   | --   | --   | 237 |
| D-2 | 30.0 | 43.0 | 13.0 | 215 | E-1 | 30.0 | 40.0 | 10.0 | 256 |
| D-1 | 30.0 | 43.0 | 13.0 | 210 | E-2 | 30.0 | 40.5 | 10.5 | 227 |
|     | --   | --   | --   | 213 |     | --   | --   | --   | 242 |
|     | --   | --   | --   | 213 |     | --   | --   | --   | 239 |

### 3. Tread Temperatures and Tire Pressures (Contd.)

## Revised Pavement Course Operation (194 miles per shift) (Contd.)

| Tire Group    | D       | E       |
|---------------|---------|---------|
| Vehicle       | C-1     | C-3     |
| Date          | 6/17/63 | 6/17/63 |
| Miles to Date | 5887    | 2487    |
| Ambient       | 76°F    |         |
| Pavement      | 92°F    |         |
|               | psig    | psig    |
|               | Start   | Start   |
|               | Temp    | Temp    |
|               | Inc     | Inc     |
|               | of      | of      |
|               | Temp    | Temp    |
| LF            | D-4     | E-3     |
| RF            | D-3     | E-4     |
| Avg. Front    |         |         |
| LR            | D-2     | E-1     |
| RR            | D-1     | E-2     |
| Avg. Rear     |         |         |
| Avg. Group    |         |         |

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FINAL REPORT

Project 20-1-110

Appendix A - "Ride" Study  
and  
Appendix B - Shallow Mud Traction

July 1963

Nevada Automotive Test Center  
A Division of Hodges Transportation Inc.  
Box 234 Carson City, Nevada

APPENDIX A

FINAL REPORT

Project 20-1-110

Comparison of Vehicle "Ride"  
as Influenced By Vehicle Configuration  
and Tire Design

July 1963

Nevada Automotive Test Center  
A Division of Hodges Transportation Inc.  
Box 234 Carson City, Nevada

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## APPENDIX A

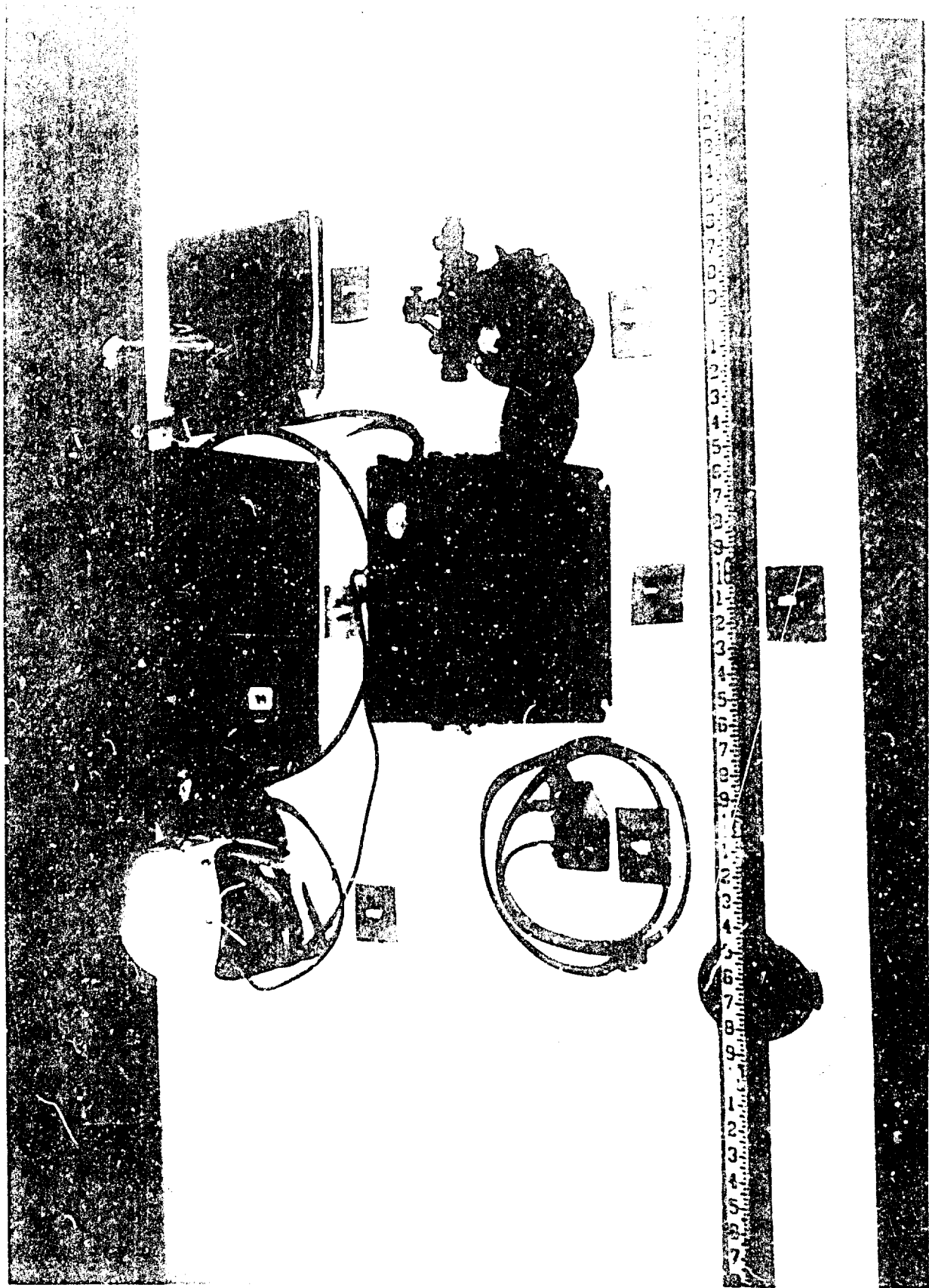
### FINAL REPORT

Project 20-1-110

This Photograph shows the Recording and Measurement Equipment Necessary to Conduct this "Ride" Study.

1. General Radio Model 761A Vibration, Displacement and Velocity Meter.
2. Sanborne Strip Chart Recorder (not used during test due to the forces acting on the recording system and absence of suitable mount; therefore, visual readings were recorded directly from the vibration meter).
3. "Lock-on" helmet with Vibration Meter Pickup used in measuring drivers' reaction to ride.
4. Vibration Meter Pickup used in measuring vehicles' reaction to ride.
5. Stadia Rod used in measuring course profile.
6. Transit used in conjunction with Stadia Rod.
7. Notebook of instrument manuals.

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## APPENDIX A

### HISTORY

Shortly after the inception of the tire tread wear and durability evaluation, Project 20-1-110, it became obvious that the "ride" severity of the "test bed" Model "C" Tournapull on the pavement, secondary and cross-country courses was limiting the desired vehicle speed. Adjustment of test tire inflation pressures was made to improve pavement "ride", but by necessity secondary and cross-country terrain was negotiated at the pressure established as the most reasonable optimum for pavement.

The tire manufacturers' representatives and the vehicle manufacturer's representative had previously observed certain "ride" characteristics of the ATAC "Goer" Tanker unit which were influenced differently by the performance of non-directional radial ply tires (Group B) when compared with the directional conventional construction tires (Group A). These observed differences were not confirmed by the performance of the Model "C" Tournapull "test beds" mounted on similar tires. The seriousness of the Model "C" Tournapull's "ride" problem was climaxed by the failure of the paved test course, Route #1, due in part to the high dynamic loads imposed by the tires during periods of random cyclic excitation which developed progressively larger areas of pavement deterioration.

The secondary road courses also suffered under these dynamic loads but the absence of public traffic on these roads provided the operators a certain latitude in avoiding known exciters.

On pavement the most sensitive tires in terms of "loping" generation were the non-directional radial ply, Group B. On secondary road surfaces the Group B tires were difficult to excite, but once excited, rate of decay was exceptionally slow compared with the directional conventional tires (Groups A and C). In cross-country the non-directional radial ply Group B tires could negotiate "rough" single impacts at a higher rate of speed than Groups A or C, but if a combination of three or more closely spaced impacts was present, the Group B tires would achieve a compound amplitude quickly reaching the intolerable limit for both driver and vehicle. The Group A and C, on the contrary, would transmit a higher initial "jerk" force but would require a considerably greater number of closely spaced impacts before an intolerable compound reaction resulted.

As the Group A and C tires became severely worn and the directional tread elements were significantly reduced, the operator's subjective "ride" experience improved, whereas the Group B tires reacted essentially without change throughout the test.

## TEST PLAN

Establishing the cause of the adverse "ride" reaction of the non-directional radial ply (Group B) tires required a subjective "ride" comparison of the non-directional radial ply tires (Group F) originally used on the "Goer" Tanker. At the conclusion of the tire tread wear and durability study a set of Group F tires formerly applied to the "Goer" Tanker were mounted on one of the Model "C" Tournapull "test beds". Although a direct comparison with the Group B tires was impossible, a complete lap of each test course with the Group F tires indicated little, if any, change in the operator's subjective "ride" experience. This comparative evaluation, however crude, identified Groups B and F as developing similar ride characteristics; consequently, this process of elimination suggested a significant difference in the "ride" reaction of the "Goer" Tanker compared with the Model "C" Tournapull "test beds". To permit a dimensional analysis of the "ride" differences between "Goer" and Model "C" Tournapull, all comparative "ride" reactions were determined by measurements expressed in terms of a "ride" index value.

Each test course was carefully surveyed for particularly significant sections which would support high density test use without change. Upon location of the test course the Group F and the Group A tires at two different inflation pressures were used to establish a constant test speed based on subjective reaction while the vibration meter simultaneously identified the significant exciters and the area of maximum effect. The inflation pressures selected for the "Ride" Study were a compromise based on different pressure build-up rates for the various tires tested as well as different build-up rates for cross-country and pavement-secondary operation. The selection of 50 psig front and 40 psig rear represented a mean pressure build-up for pavement and secondary roads from a cold starting pressure of 35-40 psig front and 25-30 psig rear. The selection of 40 psig front and 30 psig rear for all three "ride" test courses represented a mean pressure build-up for pavement and secondary roads from a cold starting pressure of 25-30 psig front and 18-23 psig rear, and for cross-country a cold starting pressure of 30-35 psig front and 20-25 psig rear.

A "Goer" Tanker was available for this comparative "ride" study and was loaded with sufficient liquid ballast to provide a "Goer" GVW equal to its rated GVW with a 5,000 gallon gasoline load (71820#). The Model "C" Tournapull was loaded at a comparable weight and weight distribution.

Two test areas on pavement, one "smooth" and one "rough"; three test areas on secondary, one which was visually "smooth" but generated a significant Model "C" Tournapull "lope", one "smooth" and one "rough"; and one test area in cross-country identified as "rough" represented six significantly different surface conditions, five of which were negotiated at two inflation pressures, while the sixth was the single cross-country area to be negotiated at only one inflation pressure.

## CONCLUSIONS

The "Goer" Tanker at rated load provides a significantly better "ride" than the Model "C" Tournapull on rough pavement and secondary road surfaces regardless of tire influence.

In cross-country terrain both vehicles are sharply sensitive to tire differences; specifically, the "Goer" equipped with radial ply non-directional tires is equally as good as the Model "C" Tournapull equipped with directional conventional tires. Inversely when the tire groups are reversed, the "ride" of both vehicles is equally severe.

The natural frequency of both vehicles is sensitive to the type of tires applied. On the Model "C" Tournapull "test bed" the directional conventional tires (Group A) develop 2.15 cycles per second; the non-directional radial ply tires (Group F) develop 1.73-1.80 cycles per second; the non-directional conventional construction tires (Group D) develop 2.00-2.16 cycles per second; and directional radial ply tires (Group E) develop 1.80 cycles per second at 50-40 psig front and 40-30 psig rear. At 30 psig front and 20 psig rear the natural frequency is reduced to 1.50 cycles per second for Groups F and E and 1.80 for Group D.

When the Group A is applied to the "Goer" the natural frequency at 50-40 psig front and 40-30 psig rear is reduced from 1.80 cycles per second to 1.67-1.70 cycles per second. Under the same conditions the Group F natural frequency is reduced from 1.80 cycles per second to 1.70 cycles per second.

Under the eleven test conditions established for the "ride" study the "Goer" vehicle equipped with the directional conventional tires (Group A) exceeded the human fatigue limit (Ride Index 0.89) on three conditions and the vehicle fatigue limit (Ride Index 1.91) on one of these three conditions. The "Goer" vehicle equipped with the non-directional radial ply tires (Group F) exceeded the human and vehicle fatigue limit in cross-country only.

A similar comparison of the influence of tire groups on the Model "C" Tournapull found the Group A tires exceeding the human fatigue limit on five conditions of which two exceeded the vehicle fatigue limit and the Group F tires exceeding the human fatigue limit on six conditions of which three exceeded the vehicle fatigue limit.

The non-directional conventional tires (Group D) and the directional radial ply tires (Group E) were only evaluated on the Model "C" Tournapull. The Group D tires exceeded the human fatigue limit on seven of the eleven conditions of which four exceeded the vehicle fatigue limit. The Group E tires exceeded the human fatigue limit on four of the eleven conditions of which three exceeded the vehicle fatigue limit.

## CONCLUSIONS (Contd.)

The subjective "ride" impressions of operators during the tread wear and durability study as well as the operator during the "ride" study confirmed the measured results in terms of "good" and "bad" but without any apparent "feel" for degree of severity once "bad" was reached.

At the beginning of the "ride" study it was necessary to evaluate a subjective "ride" impression expressed by the Model "C" Tournapull operators that one particular type of seat cushion was the most comfortable. By measuring the operator's displacement as influenced by the seat cushion, it was determined that the reduced depth cushion was more comfortable and provided less amplification of input displacement than the deep cushion, consequently the shallow cushion was used throughout the "ride" study.

The non-directional conventional construction tires (Group D) required a speed reduction of 0.6 miles per hour on the rough pavement condition and 1.6 miles per hour on the rough secondary road condition due to the violent reaction of the Model "C" Tournapull at the pre-established test speed.

When driver "ride" measurements are compared with Model "C" Tournapull "ride" measurements under identical conditions, we find the driver generally suffers a proportionately greater increase in amplitude with increased input severity.

Where significant exciters exist, a small increase in vehicle speed (i.e., 1.2 MPH) amplifies Model "C" Tournapull "ride" reaction as much as six times for the Group D tires, four times for the Group F tires and three times for the Group E tires. The Group A tires on the "Goer" indicated no significant increase under the same conditions.

## TEST RESULTS

### Measured "Ride" Reaction

The results of this study are given on the following pages in tabular and graph form.

Table I summarizes the result of the "Ride" Study comparing tire group performance in terms of vehicle "ride" index values. A "ride" index value of 0.89 is defined as being the acceptable limit of human fatigue for continuous operation.

Table II summarizes the result of the "Ride" Study comparing the performance of the Model "C" Tournapull with the "Goer" Tanker, in terms of vehicle "Ride" index value. A "ride" index of 1.91 is defined as being the acceptable limit of vehicle fatigue for continuous operation (approximately 0.8 to 0.9 G). (See GRAPH LEGEND, Figures 1 and 2).

Figure 1 illustrates the "ride" comparison on pavement of each tire group on the Model "C" Tournapull at two inflation pressures.

Figure 2 illustrates the "ride" comparison on pavement of the "Goer" versus the Model "C" Tournapull with Group A and F tires at two inflation pressures.

Figure 3 illustrates the "ride" comparison of each tire group on the Model "C" Tournapull at two inflation pressures under three conditions of secondary road surfaces.

Figure 4 illustrates the "ride" comparison under three conditions of secondary road surfaces of the "Goer" versus the Model "C" Tournapull vehicle with Group A and F tires at two inflation pressures.

Figure 5 illustrates the "ride" comparison of the Model "C" Tournapull versus driver reaction under three conditions of secondary road surfaces on Group F and D tires at two inflation pressures.

Figure 6 illustrates the same conditions as Figure 5 but with Group A and E tires.

Figure 7 illustrates the "ride" comparison of driver on deep versus shallow seat cushion under three conditions of secondary road surfaces using Group D tires on the Model "C" Tournapull at one inflation pressure.

Table 1 (Contd.)

Measures "Ride" Reaction (Contd.)

Figure 8 illustrates the "ride" comparison on cross-country as influenced by the vehicles as well as the tires at one inflation pressure.

Figure 9 illustrates the "ride" comparison of Groups D, E and F under two conditions of pavement at two test speeds on the Model "C" Tournapull and the Group A tires on the "Coar" vehicle at one inflation pressure.

TABLE 1

| <u>Condition</u>     | <u>Tire Groups</u>  |              |              |              |              |              |              |              |
|----------------------|---------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
|                      | <u>A</u>            |              | <u>F</u>     |              | <u>D</u>     |              | <u>E</u>     |              |
| Front Tire, pair     | 40                  | 50           | 40           | 50           | 40           | 50           | 40           | 50           |
| Rear Tire, pair      | <u>30</u>           | <u>40</u>    | <u>30</u>    | <u>40</u>    | <u>30</u>    | <u>40</u>    | <u>30</u>    | <u>40</u>    |
|                      | <u>"Ride" Index</u> |              |              |              |              |              |              |              |
| <u>Pavement</u>      |                     |              |              |              |              |              |              |              |
| #1, Smooth           | 0.35                | 0.68         | 0.51         | 0.50         | 0.60         | 0.30         | 0.50         | 0.31         |
| #2, Rough            | <u>1.10</u>         | <u>1.10</u>  | <u>2.30*</u> | 0.60         | <u>4.60*</u> | <u>2.00*</u> | <u>2.15*</u> | 0.72         |
| <u>Secondary</u>     |                     |              |              |              |              |              |              |              |
| #1, Smooth           | 0.54                | 0.65         | 0.50         | <u>1.20</u>  | 0.44         | <u>0.98</u>  | 0.22         | 0.54         |
| #2, Smooth           | 0.52                | <u>1.21</u>  | 0.37         | <u>1.40</u>  | 0.24         | <u>1.90</u>  | 0.28         | <u>1.40</u>  |
| #3, Rough            | 0.85                | <u>2.38*</u> | <u>0.92</u>  | <u>2.90*</u> | <u>0.91</u>  | <u>4.30*</u> | 0.75         | <u>2.00*</u> |
| <u>Cross-Country</u> |                     |              |              |              |              |              |              |              |
| Rough                | <u>2.7*</u>         | --           | <u>6.2*</u>  | --           | <u>10.2*</u> | --           | <u>5.8*</u>  | --           |

Underlined values are in excess of acceptable human fatigue limits for continuous operation.

(\*) Asterisked values are in excess of acceptable human and vehicle fatigue limits for continuous operation.

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TEST RESULTS (Contd.)

TABLE II

| Vehicle<br>Tire Group<br>Condition | Vehicle "Ride" Indices |           |           |           |               |           |           |           |
|------------------------------------|------------------------|-----------|-----------|-----------|---------------|-----------|-----------|-----------|
|                                    | Model "C" Tournapull   |           |           |           | "Goer" Tanker |           |           |           |
|                                    | A                      |           | F         |           | A             |           | F         |           |
| Inflation, Front, psig             | 40                     | 50        | 40        | 50        | 40            | 50        | 40        | 50        |
| Inflation, Rear, psig              | <u>30</u>              | <u>40</u> | <u>30</u> | <u>40</u> | <u>30</u>     | <u>40</u> | <u>30</u> | <u>40</u> |

| Pavement      | <u>"Ride" Index</u> |              |              |              |              |             |              |      |
|---------------|---------------------|--------------|--------------|--------------|--------------|-------------|--------------|------|
|               |                     |              |              |              |              |             |              |      |
| #1, Smooth    | 0.35                | 0.68         | 0.51         | 0.50         | 0.22         | 0.27        | 0.31         | 0.29 |
| #2, Rough     | <u>1.10</u>         | <u>1.10</u>  | <u>2.30*</u> | 0.80         | 0.57         | 0.65        | 0.80         | 0.75 |
| Secondary     |                     |              |              |              |              |             |              |      |
| #1, Smooth    | 0.54                | 0.65         | 0.50         | <u>1.20</u>  | 0.22         | 0.56        | 0.20         | 0.18 |
| #2, Smooth    | 0.52                | <u>1.21</u>  | 0.37         | <u>1.40</u>  | 0.20         | <u>1.40</u> | 0.35         | 0.38 |
| #3, Rough     | 0.85                | <u>2.38*</u> | <u>0.92</u>  | <u>2.90*</u> | 0.51         | <u>0.90</u> | 0.55         | 0.62 |
| Cross-Country |                     |              |              |              |              |             |              |      |
| Rough         | <u>2.70*</u>        | --           | <u>6.20*</u> | --           | <u>5.70*</u> | --          | <u>2.90*</u> | --   |

|                       | Comparison of Mean Vehicle "Ride" Indices |             |             |             |              |               |
|-----------------------|---|-------------|-------------|-------------|--------------|---------------|
|                       | Pavement                                  |             | Secondary   |             |              | Cross-Country |
|                       | Smooth                                    | Rough       | Smooth      | Smooth      | Rough        | Rough         |
| Goer @ 40-30 psig     | 0.27                                      | 0.69        | 0.21        | 0.28        | 0.53         | <u>4.30*</u>  |
| "C" Pull @ 40-30 psig | 0.43                                      | <u>1.70</u> | 0.52        | 0.45        | 0.89         | <u>4.45*</u>  |
| Goer @ 50-40 psig     | 0.28                                      | 0.78        | 0.37        | 0.49        | 0.75         | --            |
| "C" Pull @ 50-40 psig | 0.59                                      | <u>0.95</u> | <u>0.93</u> | <u>1.31</u> | <u>2.64*</u> | --            |



Underlined values are in excess of acceptable human fatigue limits for continuous operation.

(\*) Asterisked values are in excess of acceptable human and vehicle fatigue limits for continuous operation.

## GRAPH LEGEND

### Figures 1 and 2

Speed: 27.6 Miles Per Hour

| <u>Key</u>  |                 | <u>Description</u> |   |
|---|-----------------|--------------------|---|
|  | 40 - 50         | =                  | 50 PSI Front Tires<br>40 PSI Rear Tires   |
|  | 40 - 30         | =                  | 40 PSI Front Tires<br>30 PSI Rear Tires   |
|   | Cond. 1         | =                  | Smooth Road   |
|   | Cond. 2         | =                  | Rough Road  |
| -----   | "Human Limit"   | =                  | Acceptable "Human" Continuous Fatigue<br>Limit of .89* (Ride Index)   |
| _____   | "Vehicle Limit" | =                  | Acceptable Vehicle Continuous Fatigue<br>Limit of 1.91 (Ride Index) as Interpreted<br>from Goldman's "Intolerable" Limit* |
|   | Ride Index      | =                  | Displacement (inches) X frequency (cycles<br>per second)  |

Note: Speed reduced to 27.0 MPH on D Group, Condition 2, due to D Group's adverse reaction.

\* Goldman, D.E., A Review of Subjective Responses to Vibratory Motion of the Human Body in the Frequency Range 1 to 70 Cycles per Second Report No. 1, Project NM 004001, Naval Medical Research Institute, March 16, 1948.



Figure 1

# "Add" Comparison On Pavement At Constant Speed And Variable Inflation Pressure

Slide  
Number 52

52

42

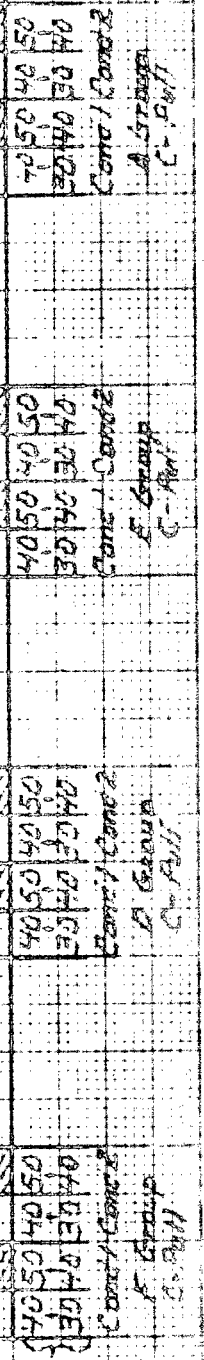
32

Vehicle  
Front

20

Vehicle  
Rear

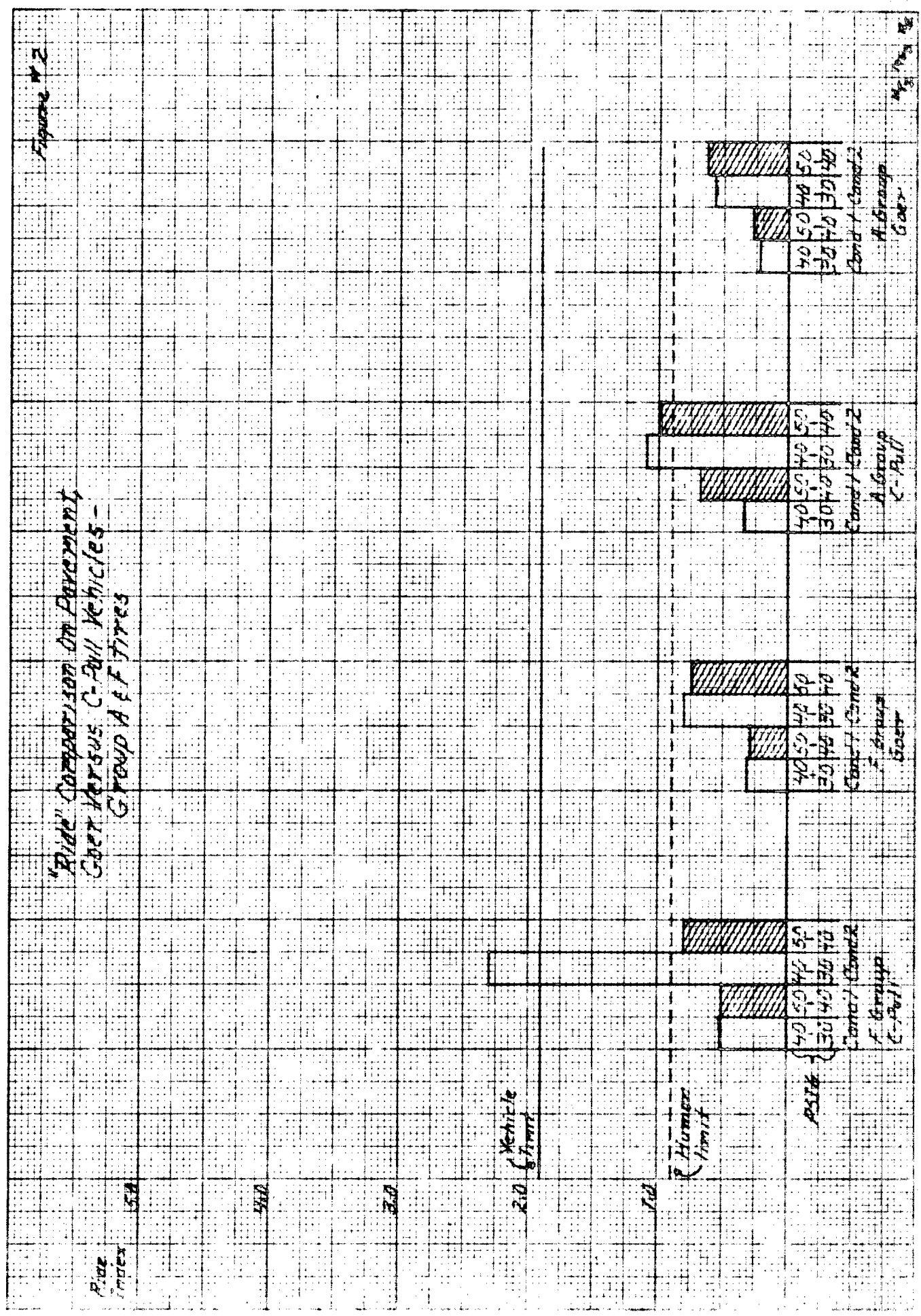
PSI



42 43 44

Figure #2



"Ride" Comparison On Pavement  
Coast Versus C-Pull Vehicles -  
Group A & F Tires



## GRAPH    L E G E N D

### Figures 3 and 4

Speed: 22.6 Miles Per Hour

| Key   | Description   |
|---|---|
|  | = 50 PSI Front Tires<br>40 PSI Rear Tires   |
|  | = 40 PSI Front Tires<br>30 PSI Rear Tires   |
| Cond. 1   | = 100 Foot Smooth Road Section Acting<br>as Lope Generator  |
| Cond. 2   | = 100 Foot Smooth Road Section  |
| Cond. 3   | = 100 Foot Road Section with Three<br>Exciters Followed by a Smooth Road<br>Section   |
| ----- "Human Limit"   | = Acceptable "Human" Continuous Fatigue<br>Limit of .89* (Ride Index)   |
| _____ "Vehicle Limit"   | = Acceptable Vehicle Continuous Fatigue<br>Limit of 1.91 (Ride Index) as Interpreted<br>from Goldman's "Intolerable" Limit* |

Note: All #3 Conditions are at 21.0 MPH or 1.6 MPH below specified speed  
due to D Group's adverse reaction.

\* Goldman, D.E., A Review of Subjective Responses to Vibratory Motion  
of the Human Body in the Frequency Range 1 to 70 Cycles per Second  
Report No. 1, Project NM 004001, Naval Medical Research Institute,  
March 16, 1948.

Figure #3

"Ride" Comparison on Secondary Roads at Constant Speed and Variable Inflation Pressure

Ride Index

5.0

4.0

3.0

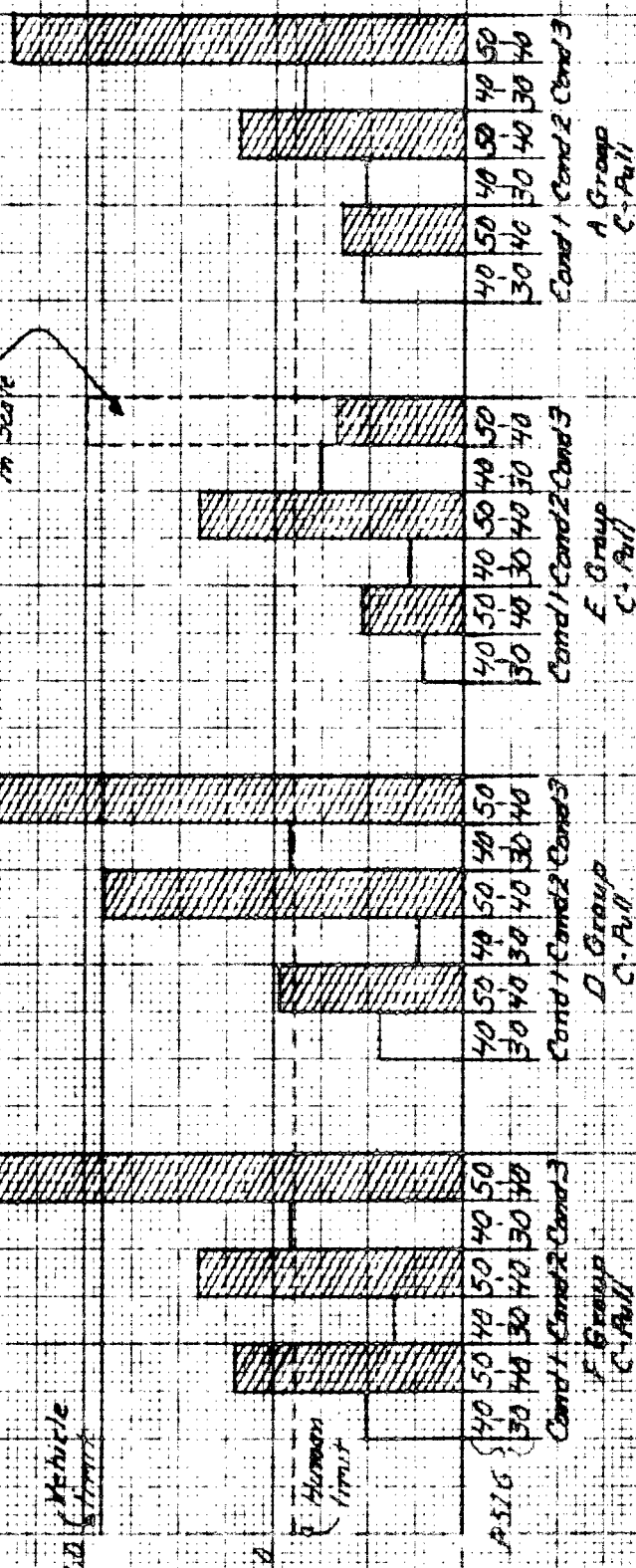
2.0

1.0

Vehicle Stimulus

Human Limit

Note: 1.67 Converted to 2.0 Due to Change in Scale



A Group  
C-Pull

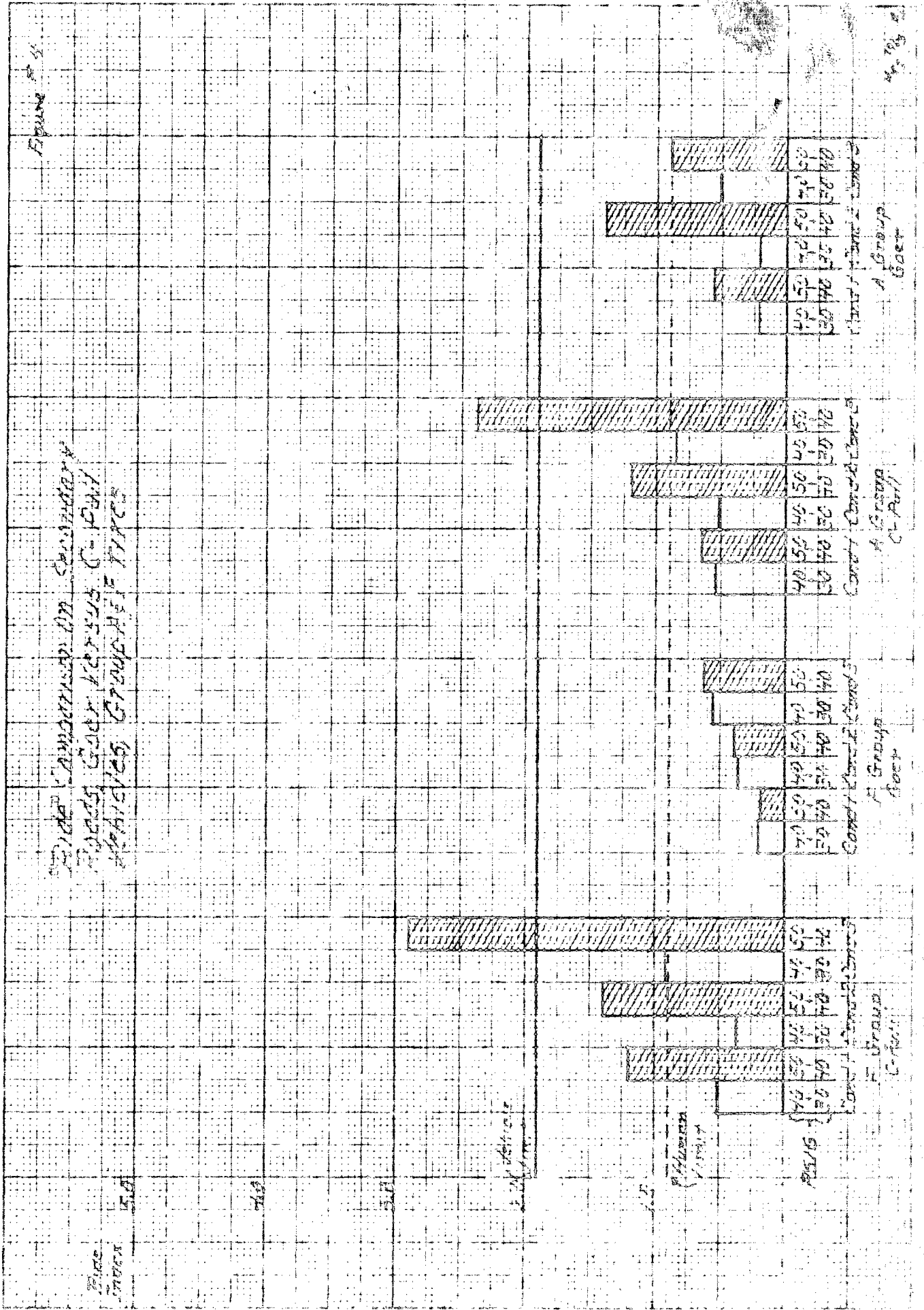
E Group  
C-Pull

D Group  
C-Pull

F Group  
C-Pull

Figure 4





Side View of the  
 1000 Series  
 1000 Series  
 1000 Series



# GRAPH    L E G E N D

## Figures 5 and 6

Speed: 22.6 Miles Per Hour

| Key   | Description   |
|---|---|
| <br>V  | = Vehicle Reaction-40 PSI Front Tires<br>30 PSI Rear Tires  |
| <br>D  | = Driver Reaction-40 PSI Front Tires<br>30 PSI Rear Tires   |
| <br>V  | = Vehicle Reaction-50 PSI Front Tires<br>40 PSI Rear Tires  |
| <br>D | = Driver Reaction-50 PSI Front Tires<br>40 PSI Rear Tires   |
| Cond. 1   | = 100 Foot Smooth Road Section Acting<br>as Lope Generator  |
| Cond. 2   | = 100 Foot Smooth Road Section  |
| Cond. 3   | = 100 Foot Road Section with Three Shallow<br>Exciters Followed by a Smooth Road Section                                    |
| ---- "Human Limit"  | = Acceptable "Human" Continuous Fatigue Limit<br>of .89* (Ride Index)   |
| _____ "Vehicle Limit"   | = Acceptable Vehicle Continuous Fatigue<br>Limit of 1.91 (Ride Index) as Interpreted<br>from Goldman's "Intolerable" Limit* |

Note: All #3 Conditions are at 21.0 MPH or 1.6 MPH below specified speed due to D Group's adverse reaction.

\* Goldman, D.E., A Review of Subjective Responses to Vibratory Motion of the Human Body in the Frequency Range 1 to 70 Cycles per Second Report No. 1, Project NM 004001, Naval Medical Research Institute, March 16, 1948.

Figure 8

Comparison of Secondary Road  
of Vehicle & Driver on 3" Seat Cushion  
at Constant Speed with Two  
Pressures

PSI

40

40

40

Vehicle  
Pressure

Pressure  
from 3"

PSI

40

50

60

70

80

90

100

110

120

130

140

150

160

170

180

190

200

210

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230

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270

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1770

1780

1790

1800

1810

1820

1830

1840

1850

1860

1870

1880

1890

1900

1910

1920

1930

1940

1950

1960

1970

1980

1990

2000

2010

2020

2030

2040

2050

2060

2070

2080

2090

2100

2110

2120

2130

2140

2150

2160

2170

2180

2190

2200

2210

2220

2230

2240

2250

2260

2270

2280

2290

2300

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2470

2480

2490

2500

2510

2520

2530

2540

2550

2560

2570

2580

2590

2600

2610

2620

2630

2640

2650

2660

2670

2680

2690

2700

2710

2720

2730

2740

2750

2760

2770

2780

2790

2800

2810

2820

2830

2840

2850

2860

2870

2880

2890

"Rude" Comparison on Secondary Road  
 of Vehicle & Driver on 3rd Class  
 at Consistent Speed with Two Tires

7 cc  
 7000x SE

2.0

3.0

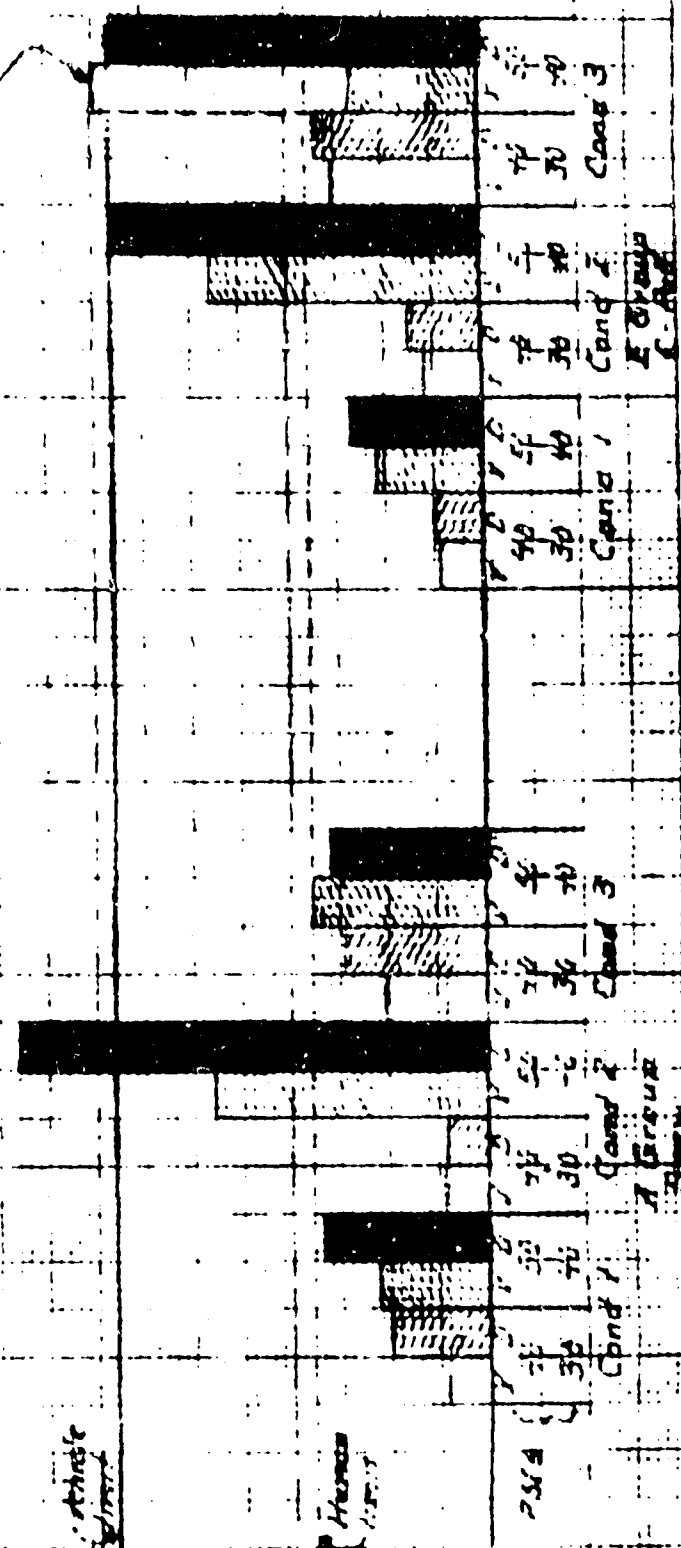
2.0  
 7000x SE

1.0

7000x SE  
 7000x SE

7000x SE

2.0  
 7000x SE  
 7000x SE








# GRAPH      L E G E N D

Figure 7

Speed: 22.6 Miles Per Hour

40 PSI Front, 30 PSI Rear

| <u>Key</u>  |                 | <u>Description</u>  |
|---|-----------------|---|
|  | Cond. 1         | = 100 Foot Smooth Road Section Acting as Lope Generator   |
|  | Cond. 2         | = 100 Foot Smooth Road Section  |
|  | Cond. 3         | = 100 Foot Road Section with Three Shallow Exciters Followed by a Smooth Road Section                                 |
| -----   | "Human Limit"   | = Acceptable "Human" Continuous Fatigue Limit of .89* (Ride Index)  |
| _____   | "Vehicle Limit" | = Acceptable Vehicle Continuous Fatigue Limit of 1.91 (Ride Index) as Interpreted from Goldman's "Intolerable" Limit* |

Note: All #3 Conditions are at 21.0 MPH or 1.6 MPH below specified speed due to D Group's adverse reaction.

\* Goldman, D.E., A Review of Subjective Responses to Vibratory Motion of the Human Body in the Frequency Range 1 to 70 Cycles per Second Report No. 1, Project NM 004001, Naval Medical Research Institute, March 16, 1948.

Best Available Copy

Figure 1

Under Compression on Secondary End of  
Driver on S.F. 3. Not Cusped at A  
Constant Speed and Rotation Pressure

Pressure  
50

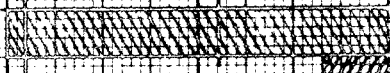
50

50

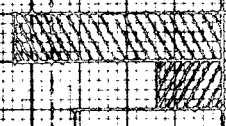
50  
60  
70  
80  
90  
100

60

Pressure  
60  
70  
80  
90  
100



50-100  
Cond. 1 2 3  
S. Seal Cusped



50-100  
Cond. 1 2 3  
S. Seal Cusped

GRAPH    L E G E N D

Figure 8

Speed: 7.4 Miles Per Hour

40 PSI Front, 30 PSI Rear

Course Involved 3 Depressions and 3 Lifts

| Key                   | Description   |
|-----------------------|---|
| ----- "Human Limit"   | = Acceptable "Human" Continuous Fatigue Limit of .89* (Ride Index)  |
| _____ "Vehicle Limit" | = Acceptable Vehicle Continuous Fatigue Limit of 1.91 (Ride Index) as Interpreted from Goldman's "Intolerable" Limit* |

\* Goldman, D.E., A Review of Subjective Responses to Vibratory Motion of the Human Body in the Frequency Range 1 to 70 Cycles per Second Report No. 1, Project NM 004001, Naval Medical Research Institute, March 16, 1948.

Figure 10 B

Side Comparison for Time & Vehicle on  
Cross Country at Constant Speed  
With and Without Pressure

Side  
Index

100

90

80

70

60

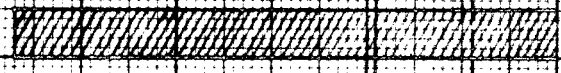
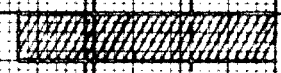
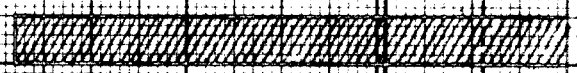
50

40

30

Vehicle  
Limit

Human  
Limit



A Group  
C-PU  
100

E Group  
C-PU  
60

F Group  
C-PU  
50

F Group  
GCM  
40

A Group  
C-PU  
30



A Group  
GCM  
20

100 90 80 70 60 50 40 30 20

## GRAPH    L E G E N D

Figure 9

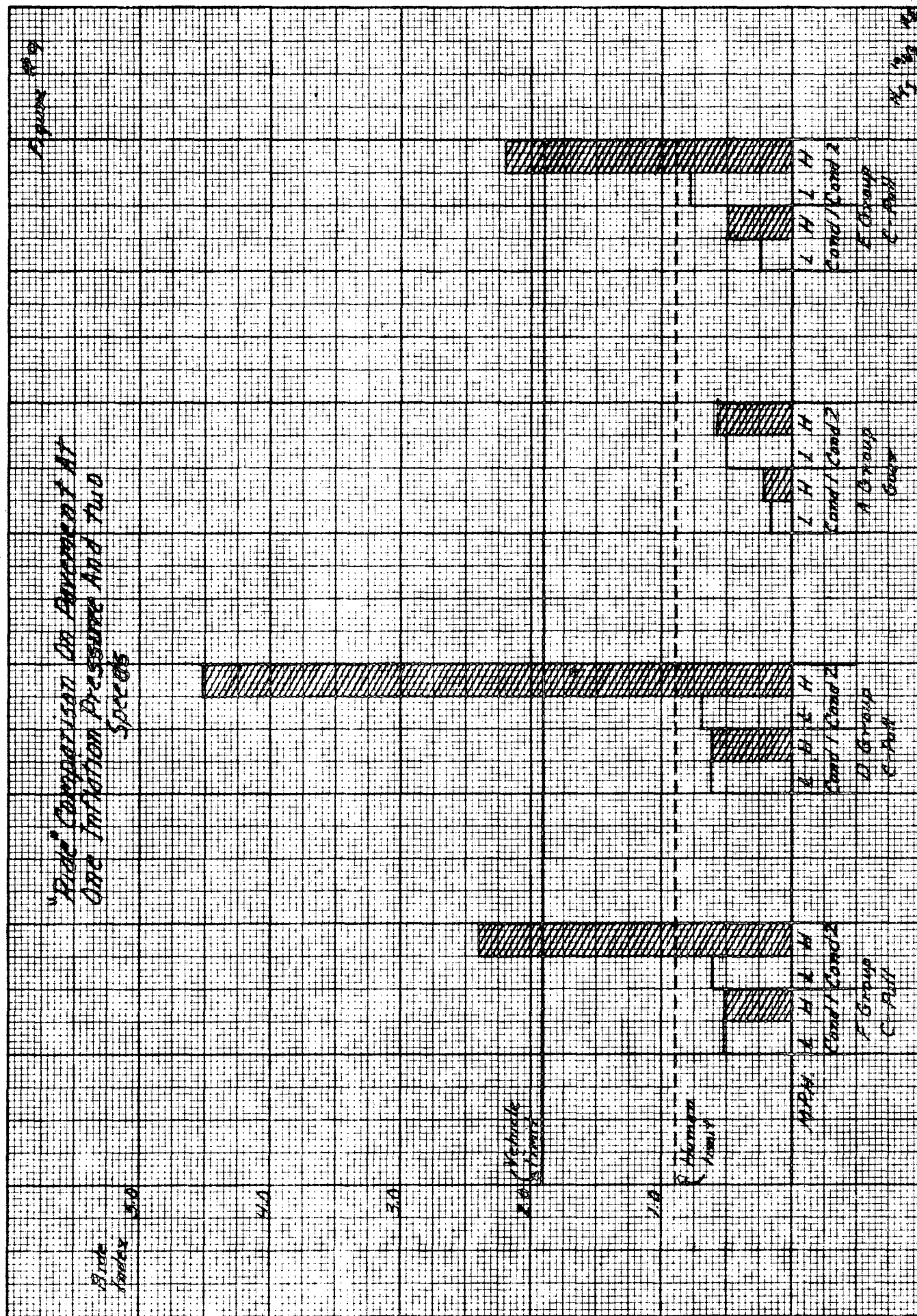
40 PSI Front, 30 PSI Rear

| Key   | Description   |
|---|---|
| <br>L  | = 26.4 Miles Per Hour   |
| <br>H | = 27.6 Miles Per Hour   |
| Cond. 1   | = Smooth Road   |
| Cond. 2   | = Rough Road  |
| ----- "Human Limit"   | = Acceptable "Human" Continuous Fatigue Limit of .89* (Ride Index)  |
| _____ "Vehicle Limit"   | = Acceptable Vehicle Continuous Fatigue Limit of 1.91 (Ride Index) as Interpreted from Goldman's "Intolerable" Limit* |

\* Goldman, D.E., A Review of Subjective Responses to Vibratory Motion of the Human Body in the Frequency Range 1 to 70 Cycles per Second Report No. 1, Project NM 004001, Naval Medical Research Institute, March 16, 1948.

Figure #9

"Ride" Comparison On Pavement At  
One Inflation Pressure And Two  
Speeds



## TEST RESULTS (Contd.)

### Subjective "Ride" Reaction

The following table reflects the operator's "ride" impressions of the two tire Groups D and E which were added to the tread wear and durability test and the tire Group F which was of similar construction and design as the Group B tires.

| Preference<br>Driver # | Pavement |          |          |          |          |          |          | Secondary |          |          |          |          |          |          | Cross-Country |          |          |          |          |          |          |
|------------------------|----------|----------|----------|----------|----------|----------|----------|-----------|----------|----------|----------|----------|----------|----------|---------------|----------|----------|----------|----------|----------|----------|
|                        | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> | <u>5</u> | <u>6</u> | <u>7</u> | <u>1</u>  | <u>2</u> | <u>3</u> | <u>4</u> | <u>5</u> | <u>6</u> | <u>7</u> | <u>1</u>      | <u>2</u> | <u>3</u> | <u>4</u> | <u>5</u> | <u>6</u> | <u>7</u> |
| 1st                    | DE       | DE       | -        | DE       | DE       | -        | -        | E         | E        | DE       | E        | DE       | E        | -        | FE            | -        | FE       | FE       | -        | FE       | FE       |
| 2nd                    | F        | F        | -        | F        | F        | -        | -        | DF        | DF       | F        | DF       | F        | DF       | -        | D             | -        | -        | D        | D        | D        | D        |

## TEST PROGRAM

### Test Courses

Pavement - A portion of Nevada Automotive Test Center's highway pavement test course #2 (abandoned U.S. Highway 50) was chosen to provide two test sections. Test section #1 was smooth, whereas test section #2 (See Road Profile of Pavement Test Section Figures #1 and #2) was of rolling contour featuring two major excitors.

Secondary - A portion of Nevada Automotive Test Center's secondary test course having a compaction of 300+ PSI was chosen to provide three test sections. Test section #1 was a visually smooth surface which generated "lope" in the Model "C" Tournapull units. Test section #2 was smooth surface creating no lope. Test section #3 (See Road Profile of Secondary Test Section #3 Figures #3 and #4) was of rolling contour featuring three major excitors.

Cross-Country - A section of Nevada Automotive Test Center's cross-country test course was chosen as a severe but not extreme condition. This test section provided three excitors (See Road Profile of Cross-Country Test Section Figure #5).



Figure #1

Plan Profile of Pavement Test Section #2  
Indicating Major Exciters  
12 ft 40 ft

As Wheel Did

Grade Line

133' Elev

16'

133'

2.3" Depth

Scale  
Vert 1" = 1.5'  
Horiz 1" = 4'



Post Section #2 Cont

Figure #2

Base of Section #2 Cont

Indicating No. of Feet

Section 40 ft

1.98" Depth

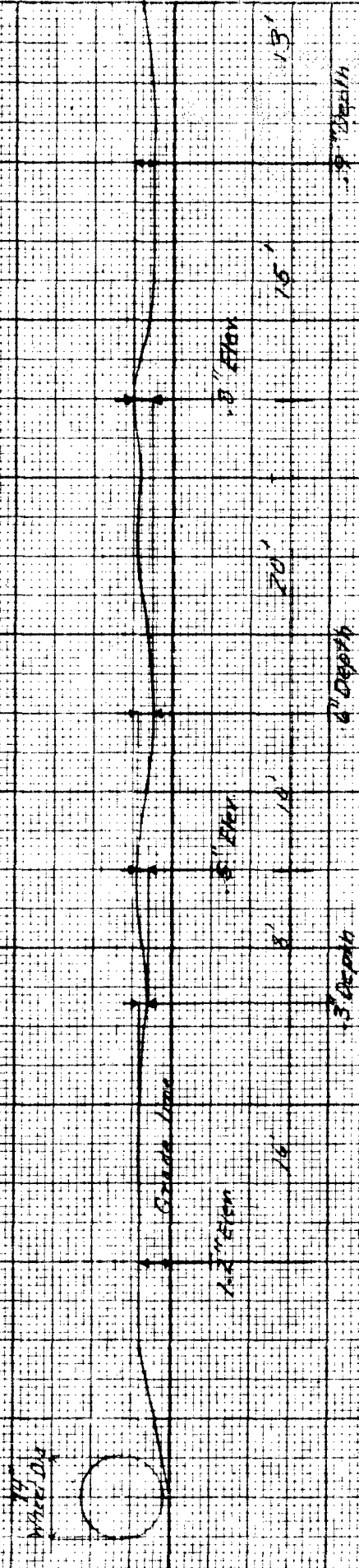
Scale

Vert 1" = 1.5'

Horiz 1" = 4'

Figure #3

# Good Profile of Secondary Test Section #3 Indicating Major Exciters First 100 ft



Scale  
 Vert 1" = 6"  
 Horiz 1" = 10'

East Section 14 Cont.  
Figure 14

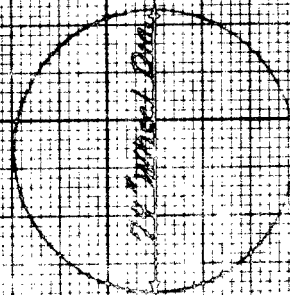
East Profile of Secondary East Section 14  
Indicating Major Features  
Second 100 FT



SCALE  
VERT. 1" = 10'  
HORIZ. 1" = 10'

Figure 10.5

ROAD PROFILE OF CROSS COUNTRY TEST SECTION  
INDICATING MAJOR EXCISES



Grade Line

20' Elevation

25' Elevation

31' Elevation

21' 3"

11'

26'

3'

5'

4.0' Depth

3.0' Depth

1.2' Depth

SCALE

VERT. 1" = 8'

HORZ. 1" = 4'

## TEST PROGRAM (Contd.)

### Test Vehicles

One Model "C" Tournapull

One "Goer" Tanker XM438E2

### Test Tires

Two of the five groups which ran on the tread wear and durability evaluation (Groups D and E) were subjected to the "ride" study. The Groups A, B and C tires were not available but a Group A and a Group F were substituted and were of similar design and construction as the Group A and Group B tires. Thus the following test groups were subjected to the "ride" evaluation:

Group A, Conventional construction directional tread.

Group D, Conventional construction non-directional tread.

Group E, Radial ply construction directional tread.

Group F, Radial ply construction non-directional tread.

### Test Procedure

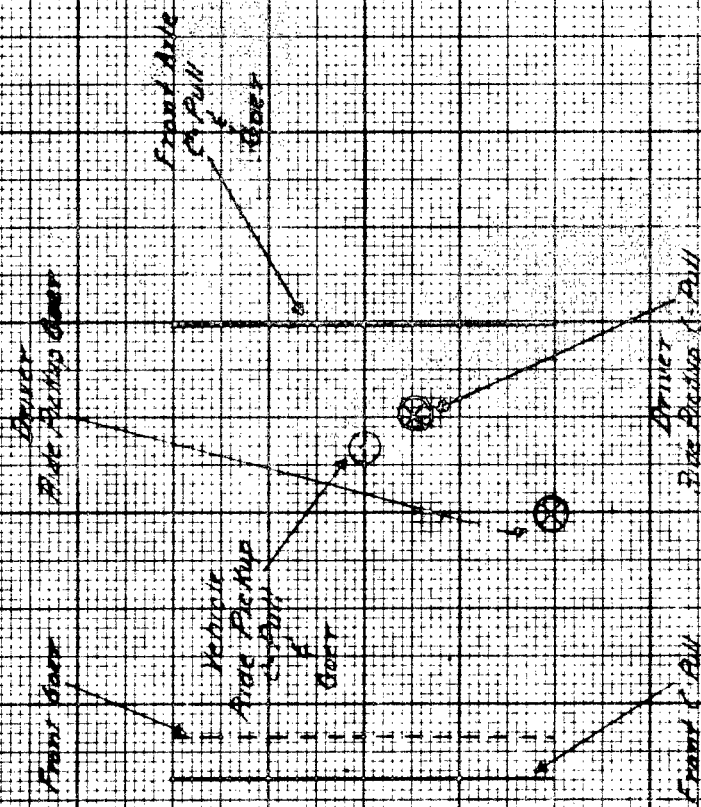
To evaluate comparative vehicle "ride" a vibration pickup location common to both Model "C" Tournapull and the "Goer" Tanker vehicle was chosen (approximately on centerline and 2 feet 7 inches ahead of the front axle). An average of two runs plus reruns as required were made at each inflation pressure, under each test condition, for the three test courses, on each group of test tires.

To evaluate driver reaction to vehicle "ride" a lock-on helmet was instrumented with a vibration meter pickup.

The following schematic shows the location of the Vibration Meter Pickups relative to the front axle position of both the Model "C" Tournapull and the "Goer" Tanker vehicle.



Field Survey  
 Placement of Instrument Meter Pickup  
 In Relation to Front Side Center Line  
 Comparing C-Pull & Goer Vehicles



Scale  
 $\frac{1}{4}'' = 1'$

APPENDIX B

FINAL REPORT

Project 20-1-110

Shallow Mud Traction of  
Tire Groups A and B Type

July 1963

Nevada Automotive Test Center  
A Division of Hodges Transportation Inc.  
Box 234 Carson City, Nevada

APPENDIX

FINAL REPORT

Project 20-1-110

Upper Photograph

Mud Test Area

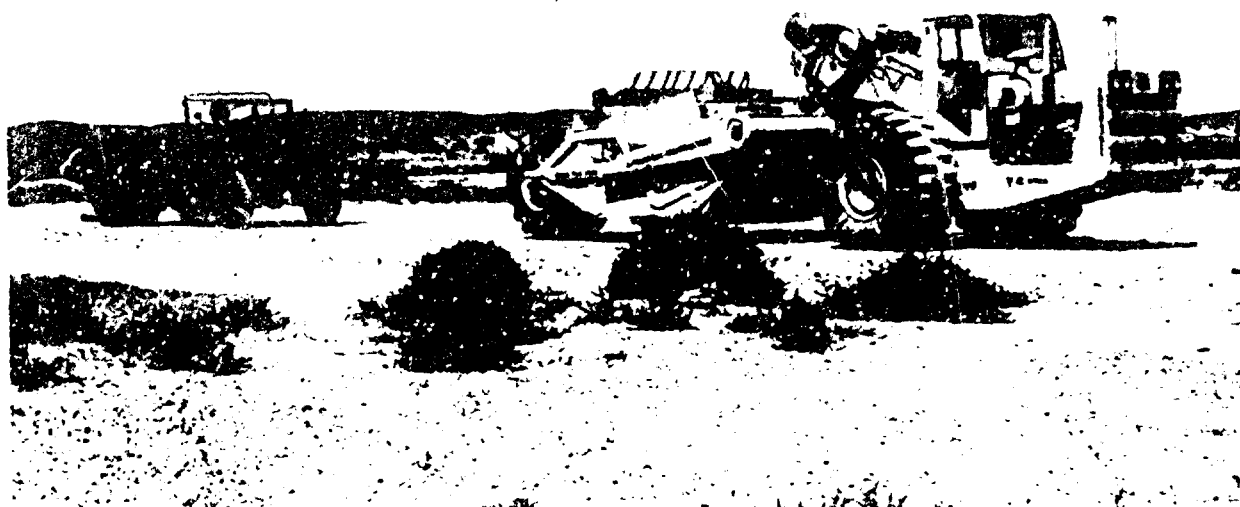
Lower Photograph

Mud Test Equipment Conveyor

NOT REPRODUCIBLE



Best Available Copy



## APPENDIX A

### HISTORY

Shortly after the inception of the tire tread wear and durability evaluation, Project 20-1-110, it became obvious that the "ride" severity of the "test bed" Model "C" Tournapull on the pavement, secondary and cross-country courses was limiting the desired vehicle speed. Adjustment of test tire inflation pressures was made to improve pavement "ride", but by necessity secondary and cross-country terrain was negotiated at the pressure established as the most reasonable optimum for pavement.

The tire manufacturers' representatives and the vehicle manufacturer's representative had previously observed certain "ride" characteristics of the ATAC "Goer" Tanker unit which were influenced differently by the performance of non-directional radial ply tires (Group B) when compared with the directional conventional construction tires (Group A). These observed differences were not confirmed by the performance of the Model "C" Tournapull "test beds" mounted on similar tires. The seriousness of the Model "C" Tournapull's "ride" problem was climaxed by the failure of the paved test course, Route #1, due in part to the high dynamic loads imposed by the tires during periods of random cyclic excitation which developed progressively larger areas of pavement deterioration.

The secondary road courses also suffered under these dynamic loads but the absence of public traffic on these roads provided the operators a certain latitude in avoiding known exciters.

On pavement the most sensitive tires in terms of "lope" generation were the non-directional radial ply, Group B. On secondary road surfaces the Group B tires were difficult to excite, but once excited, rate of decay was exceptionally slow compared with the directional conventional tires (Groups A and C). In cross-country the non-directional radial ply Group B tires could negotiate "rough" single impacts at a higher rate of speed than Groups A or C, but if a combination of three or more closely spaced impacts was present, the Group B tires would achieve a compound amplitude quickly reaching the intolerable limit for both driver and vehicle. The Group A and C, on the contrary, would transmit a higher initial "jerk" force but would require a considerably greater number of closely spaced impacts before an intolerable compound reaction resulted.

As the Group A and C tires became severely worn and the directional tread elements were significantly reduced, the operator's subjective "ride" experience improved, whereas the Group B tires reacted essentially without change throughout the test.

## TEST RESULTS

Figure 1 indicates the maximum traction developed by the two groups tested at each inflation pressure under investigation. Also shown on this graph at two inflation pressures is a profile of tire penetration in the test track. From these profiles the portion of the tread surface providing the most aggressive traction is apparent.

Figure 2 illustrates the complete Group A traction curve for each inflation pressure tested.

Figure 3 illustrates the complete Group F traction curve for each inflation pressure tested.

## TEST PROGRAM

### Test Course

A test course area was selected to provide high natural compaction affording minimal tire penetration and low coefficient of friction (.17-.25) when wet. The character of this course may be compared with wet grass matted slopes.

Separate test courses were constructed and used each day of test operation. Each test course was approximately 65 feet in length and 20 feet in width.

### Test Vehicle and Dynamometer Unit

A Model "C" Tournapull was used as the "test bed" unit and an M-34 2 1/2 ton 6x6 vehicle, fully instrumented for this study, was used as the dynamometer unit.

### Test Procedure

With the "test bed" vehicle attached to the Emery Load Cell System installed in the dynamometer unit the two vehicles, "test bed" vehicle leading, moved down the test course approach apron and stabilized at test speed with essentially zero pounds tractive force before entering the mud pit. After the "test bed" vehicle had entered the mud pit, the dynamometer vehicle slowly applied a resisting force inducing "test bed" wheel slip until zero forward motion or vehicle stall condition was achieved although the wheel speed of the "test bed" vehicle was maintained constant. Ground speed was recorded by means of a fifth wheel instrumented with a Weston DC tachometer generator. Two signals being produced simultaneously (pounds drawbar force and ground speed) were integrated and plotted by means of HTI function plotting recorder. This provided a recording of the complete traction curve for each run. An average of six runs was made at each inflation pressure for each group tested.

# DYNAMIC TRACTION STUDY IN SHALLOW MUD

PROJECT 20-1-110

MAXIMUM TRACTION GROUPS A&F

FIGURE 1

PROFILE OF TIRE PENETRATION

GROUND LEVEL

PROFILE OF TIRE PENETRATION

GROUND LEVEL

PROFILE OF TIRE PENETRATION

GROUND LEVEL

PROFILE OF TIRE PENETRATION

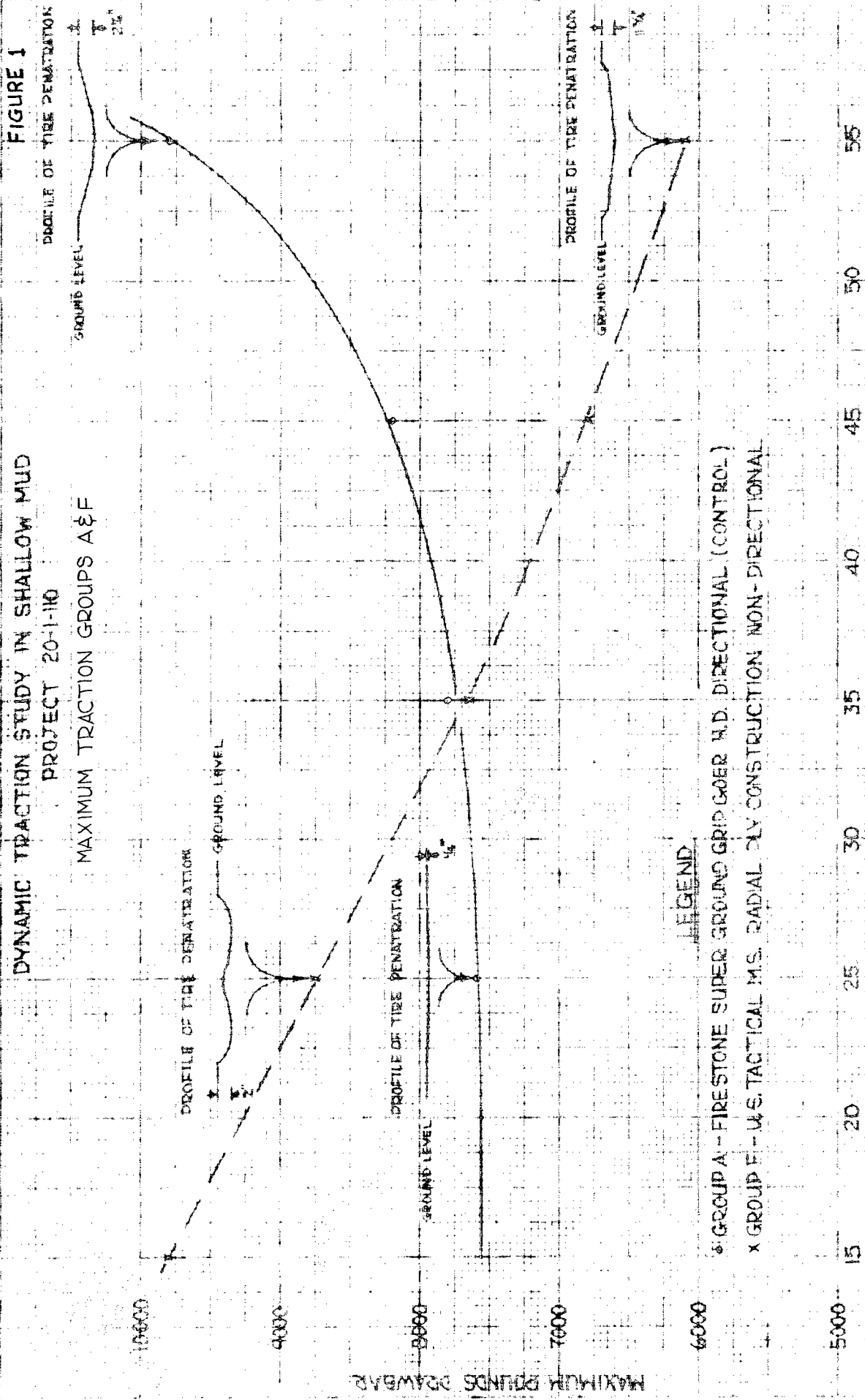
GROUND LEVEL

## LEGEND

\* GROUP A - FIRESTONE SUPER GRIND GRIP 60ER W.D. DIRECTIONAL (CONTROL)

x GROUP F - U.S. TACTICAL M.S. RADIAL T.V. CONSTRUCTION NON-DIRECTIONAL

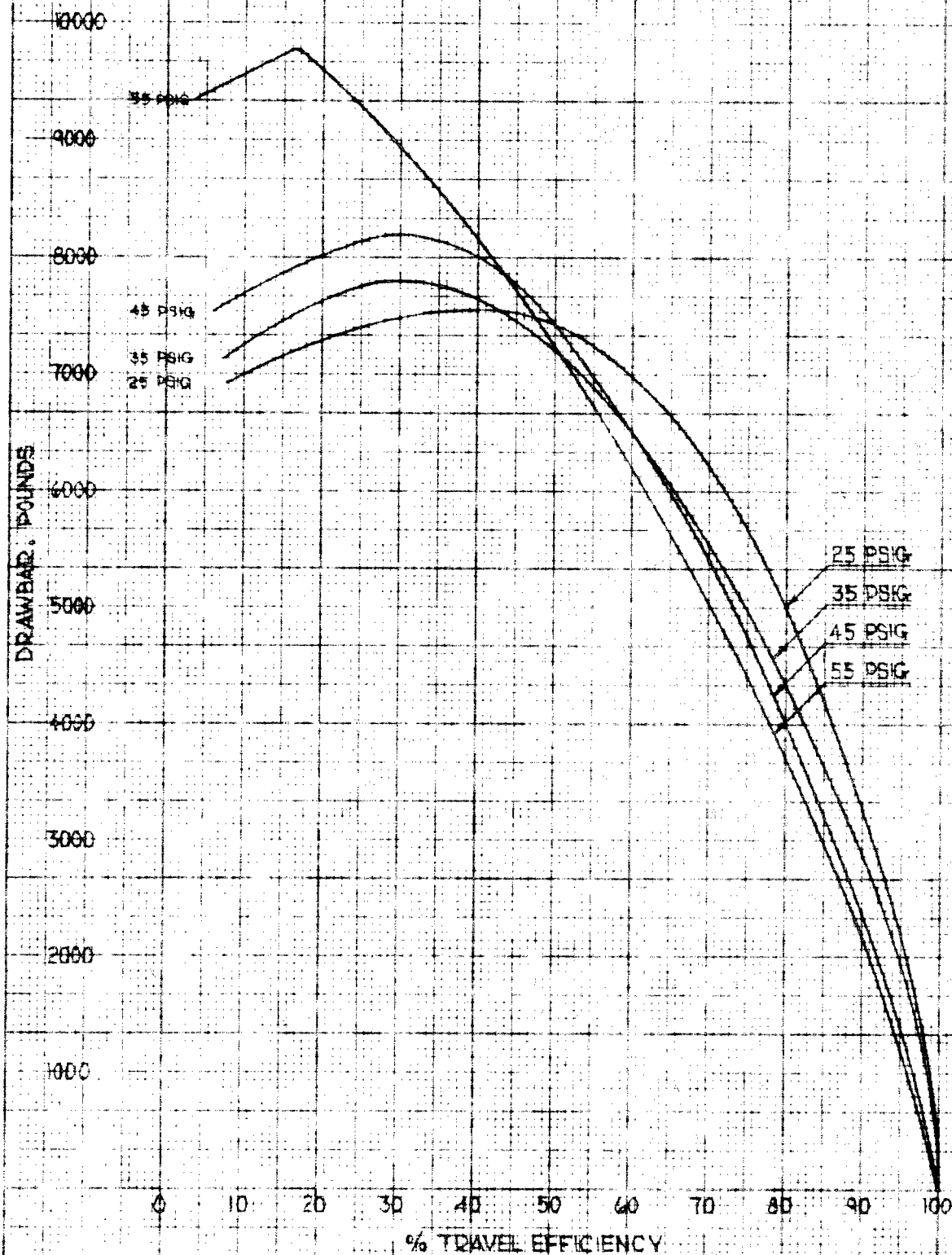
INFLATION, PSIG



MAXIMUM POUNDS DRAWBAR

DYNAMIC TRACTION IN SHALLOW MUD  
GROUP "A" TIRES  
PROJECT 20-1110

FIGURE 2

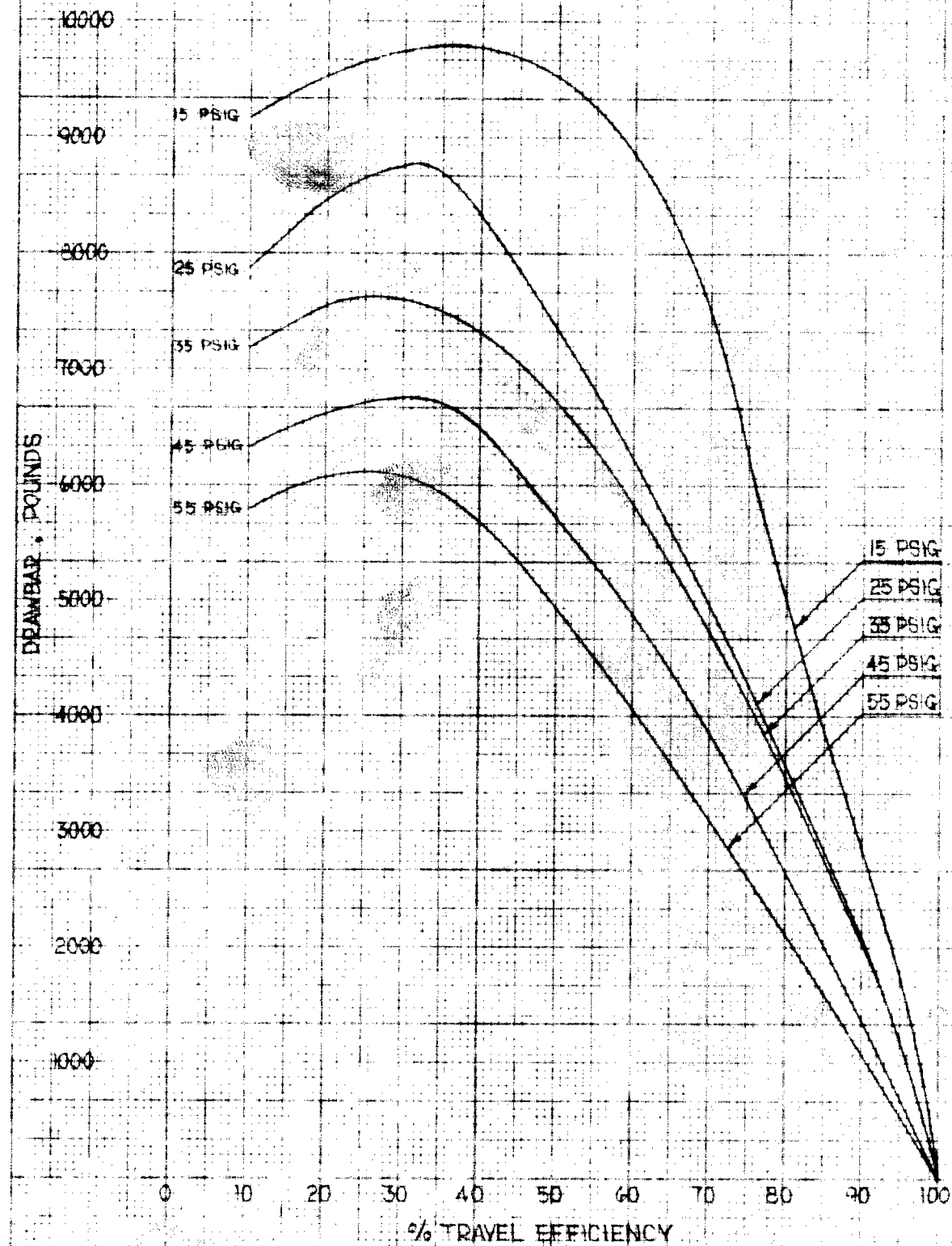


SCALE: 1 INCH = 1000 LBS

# DYNAMIC TRACTION IN SHALLOW MUD

FIGURE 3

GROUP F TIRES  
PROJECT 20-110



SCALE: 1 SQ. = 66.7 LBS.

M. B. W.

## DEEP MUD TEST

### Discussion

A specially constructed pit was required in which the depth of mud was 12 inches, the length of the pit was 220 feet and the width 40 feet. The consistency of the mud was maintained to a state wherein the vehicle would become immobile before the 220 feet distance was reached. The evaluation of one tire versus the other was made on the basis of distance traveled versus time. The vehicle remained in the same transmission gear throughout all tests, and when it became immobile the tires would spin out and not stall out. The test bed vehicle was such that only the front drive axle could be used; therefore, throughout all tests the rear axle was non-driving and the same set of tires remained on the rear axle throughout all tests. Experiments were conducted in respect to what effect inflation would have, and since there was no effect, all tests were conducted at a standard setting of 40 psi per tire. The depth of mud was determined to be the maximum allowable depth without high centering the vehicle. Inasmuch as no torque was transmitted to the rear axle, it was observed throughout each test that these tires would slide and in turn build up a large quantity of mud directly in front of each wheel. By the resistance created at this point, it increased the drag on the vehicle and in turn the front driving tires were called upon to do more work than would be expected if both axles were driving. Therefore, these tests are only a comparative type test of the three experimental groups as compared with the control group. By reviewing the attached data it will be noticed that the control tires, along with the experimental tires, have operated through the pit a total of three runs each, alternating from the control to the experimental, etc. After each run, the pit was floated down with a leveling device.

Due to a test bed vehicle breakdown, we were unable to compare the Ground Grip Directional Grooved Lugs.

TEST RESULTS:

FIRESTONE GROUND GRIP DIRECTIONAL DESIGN

(Control)

| <u>Time</u>       | <u>Distance</u> | <u>Rating</u> |
|-------------------|-----------------|---------------|
| 1. 41 Sec.        | 98' 10"         |               |
| 3. 42 Sec.        | 101' 3"         |               |
| 5. <u>43 Sec.</u> | <u>94' 10"</u>  |               |
| Total..126 Sec.   | 294' 11"        |               |
| Average..42 Sec.  | 98' 3"          | 100           |

SUPER GROUND GRIP GOER

| <u>Time</u>       | <u>Distance</u> | <u>Rating</u> |
|-------------------|-----------------|---------------|
| 2. 91 Sec.        | 177' 10"        |               |
| 4. 82 Sec.        | 165' 9"         |               |
| 6. <u>79 Sec.</u> | <u>161' 1"</u>  |               |
| Total..252 Sec.   | 504' 8"         |               |
| Average.. 74 Sec. | 168' 2"         | 171           |

FIRESTONE GROUND GRIP DIRECTIONAL DESIGN

(Control)

| <u>Time</u>         | <u>Distance</u> | <u>Rating</u> |
|---------------------|-----------------|---------------|
| 1. 54.5 Sec.        | 86' 9"          |               |
| 3. 58 Sec.          | 86' 1"          |               |
| 5. <u>54.5 Sec.</u> | <u>85' 1"</u>   |               |
| Total..167 Sec.     | 257' 11"        |               |
| Average..55.6 Sec.  | 85' 11"         | 100           |

ND-CC GOER

| <u>Time</u>         | <u>Distance</u> | <u>Rating</u> |
|---------------------|-----------------|---------------|
| 2. 26 Sec.          | 48' 3"          |               |
| 4. 24 Sec.          | 47' 3"          |               |
| 6. <u>26 Sec.</u>   | <u>48' 7"</u>   |               |
| Total...76 Sec.     | 144' 1"         |               |
| Average...25.3 Sec. | 48'             | 56            |



## APPENDIX

|                              |       |
|------------------------------|-------|
| I. Abbreviations and Symbols | p i   |
| II. Glossary of Trade Names  | p ii  |
| III. Deflection Sheets       | p iii |

## APPENDIX I

### ABBREVIATIONS AND SYMBOLS

|      |  |
|------|--|
| °C   | Degrees Centigrade                                       |
| °F   | Degrees Fahrenheit                                       |
| FR-S | Firestone Rubber - Synthetic<br>(styrene-butadiene type) |
| in   | Inches   |
| lb   | Pounds   |
| NR   | Natural Rubber   |
| psi  | Pounds per square inch                                   |

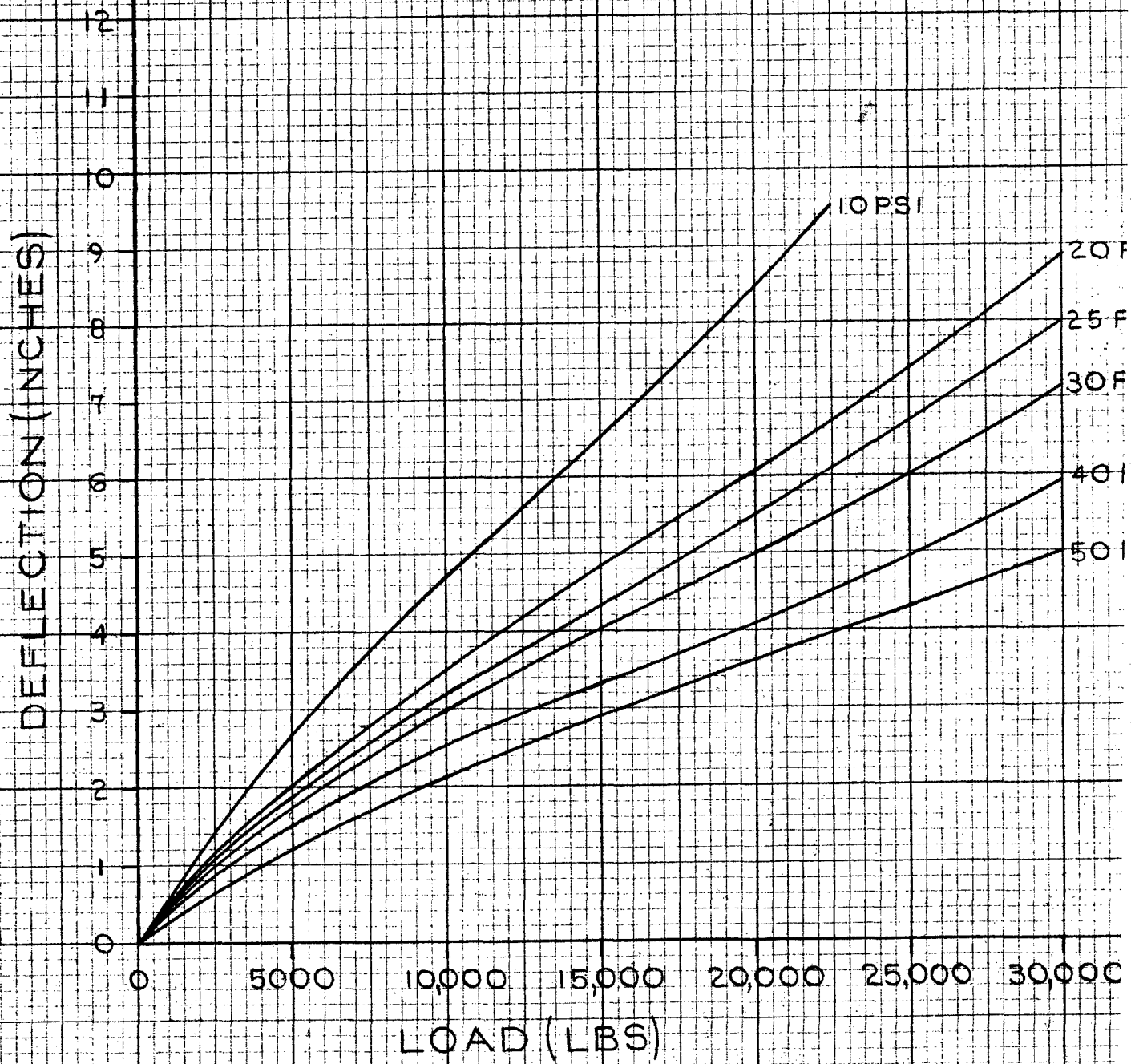
APPENDIX II

GLOSSARY OF TRADE NAMES

| <u>TRADEMARK<br/>OR DESIGNATION</u> | <u>COMPOSITION</u>  | <u>USE</u> | <u>SOURCE</u>               |
|-------------------------------------|---|------------|-----------------------------|
| Isoprene                            | polyisoprene  | Elastomer  | Shell Chemical              |
| Diene                               | polybutadiene   | Elastomer  | Firestone Tire & Rubber Co. |
| FR-S 123                            | butadiene-styrene copolymer<br>oil masterbatch-31 phR oil | Elastomer  | Firestone Tire & Rubber Co. |
| Hypalon                             | chlorosulfonated polyethylene                             | Elastomer  | duPont                      |
| Neoprene                            | polychloroprene   | Elastomer  | duPont                      |

①

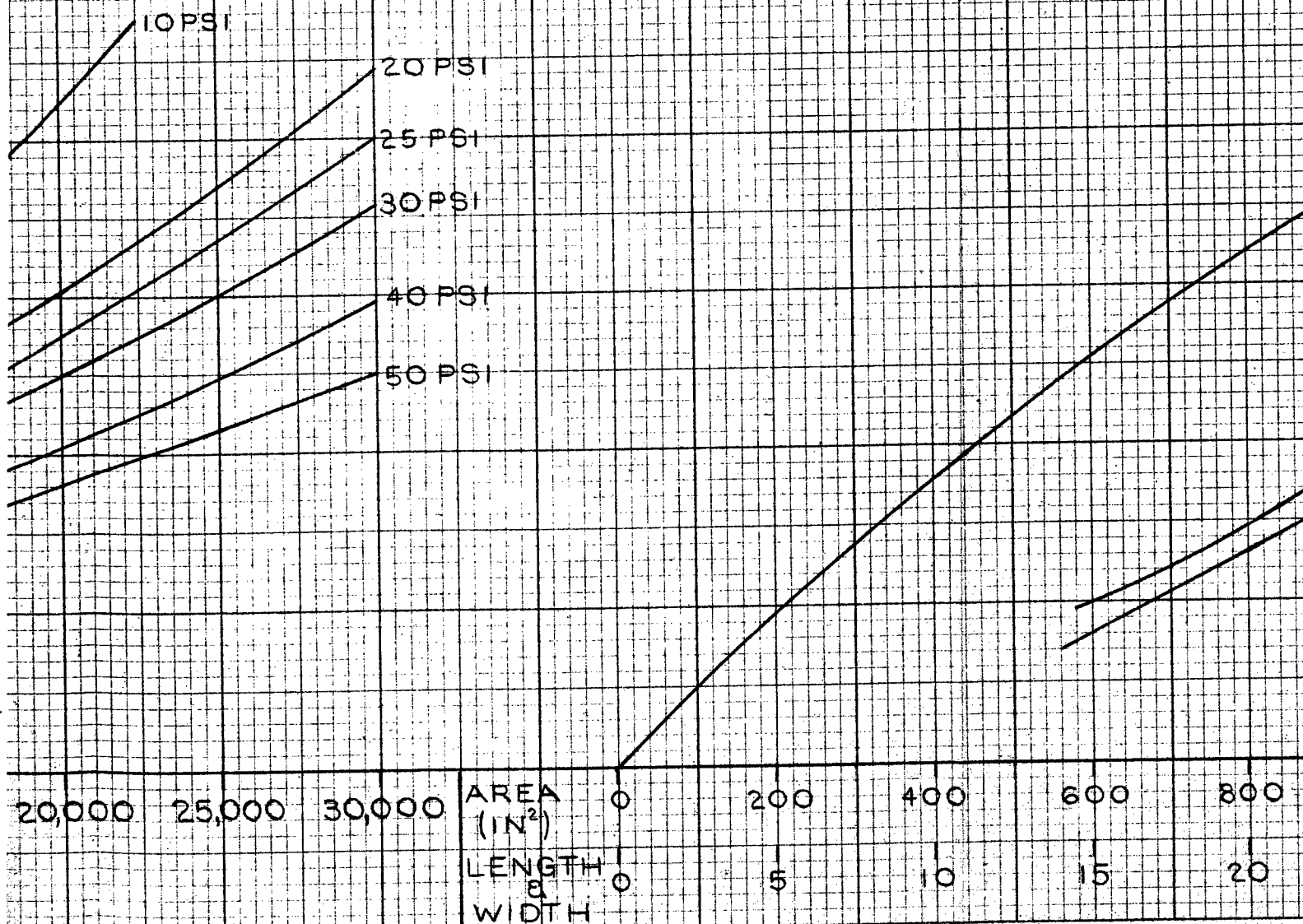
# 29.5-25 SUPER GROUND LOAD-DEFLECTION~(



2

# SUPER GROUND GRIP GOER (16)

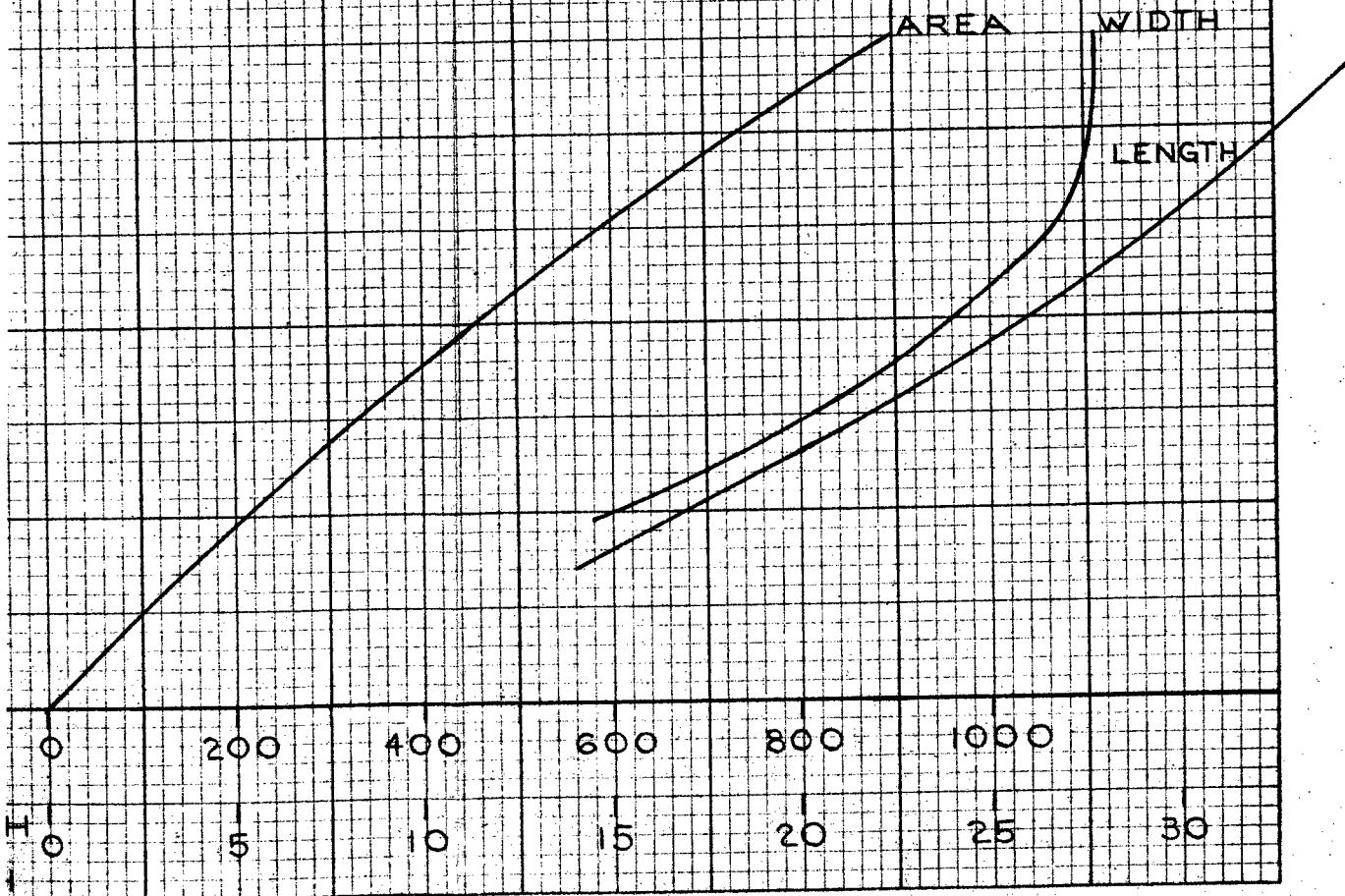
## DEFLECTION-CONTACT AREA



3

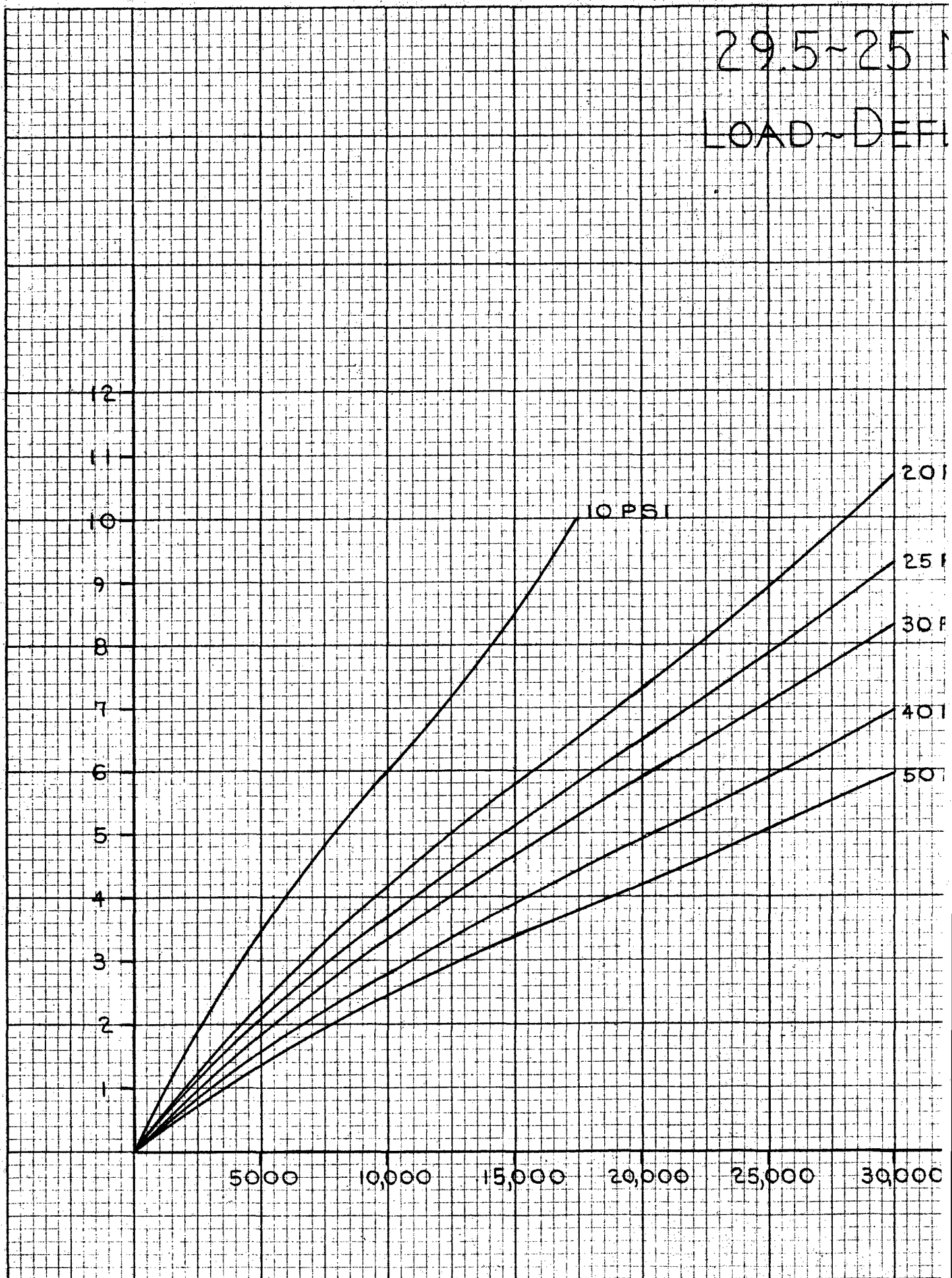
JP GOER (16)

ACT AREA



①

29.5~25  
LOAD~DEF

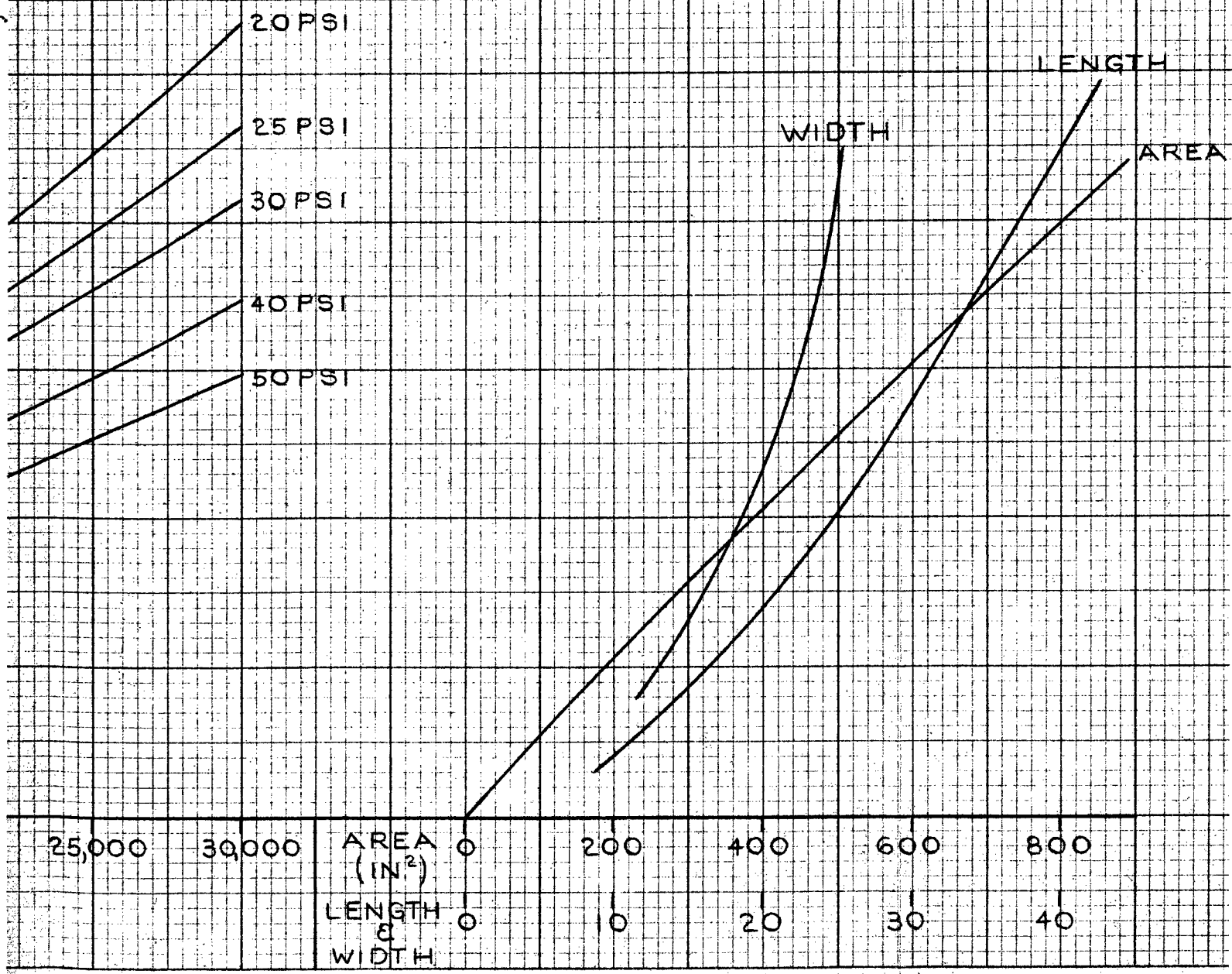




2

# 29.5-25 ND-CC GOER(16)

## LOAD~DEFLECTION~CONTACT AREA





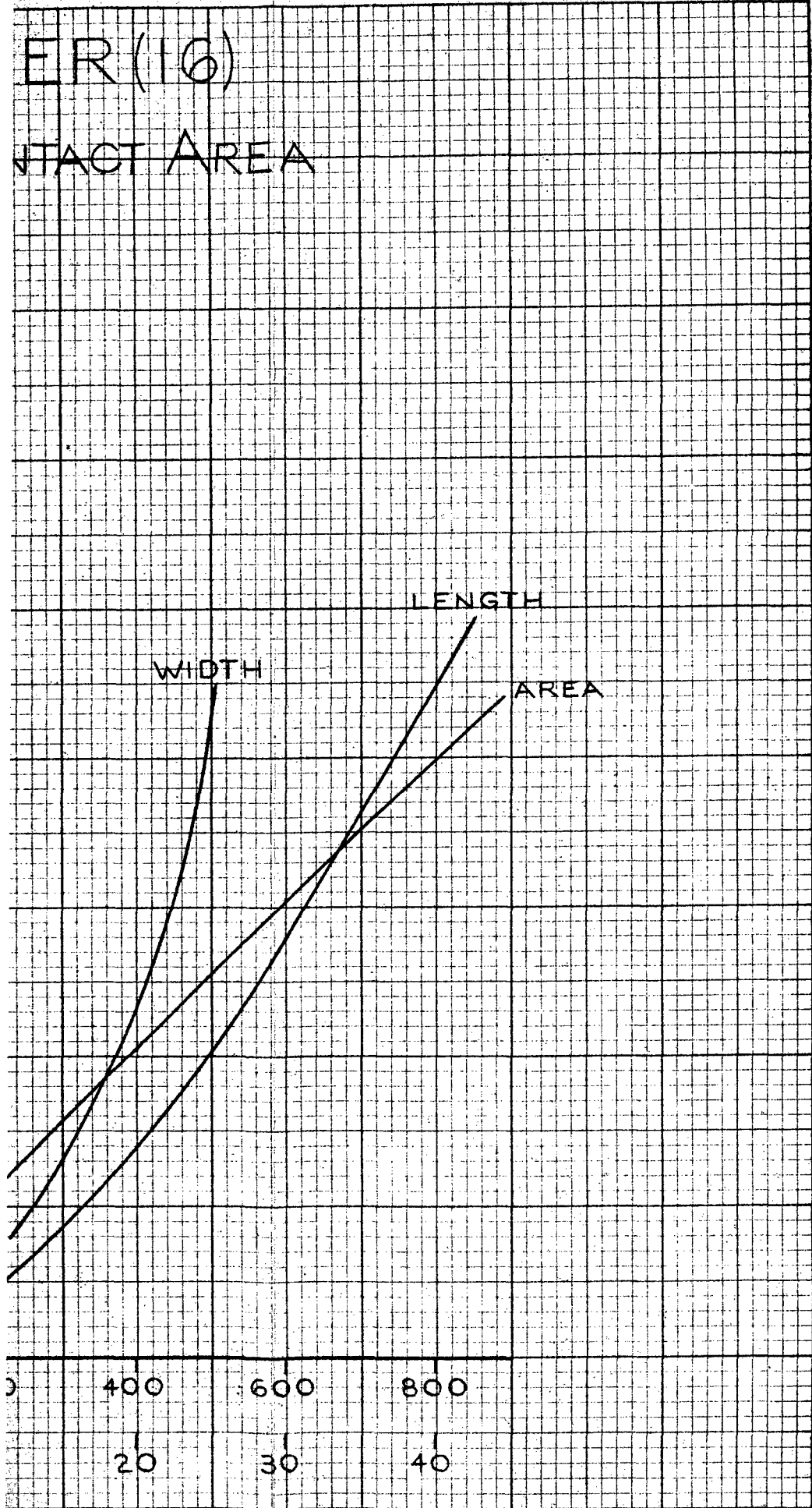
ER(16)

CONTACT AREA

WIDTH

LENGTH

AREA



①

29.5-25 S

LOAD-[

K&E 10 X 10 TO THE INCH 35F 7LG  
KEUFFEL & ESSER CO. MA U.S.A.

DEFLECTION (INCHES)

12  
11  
10  
9  
8  
7  
6  
5  
4  
3  
2  
1  
0

0

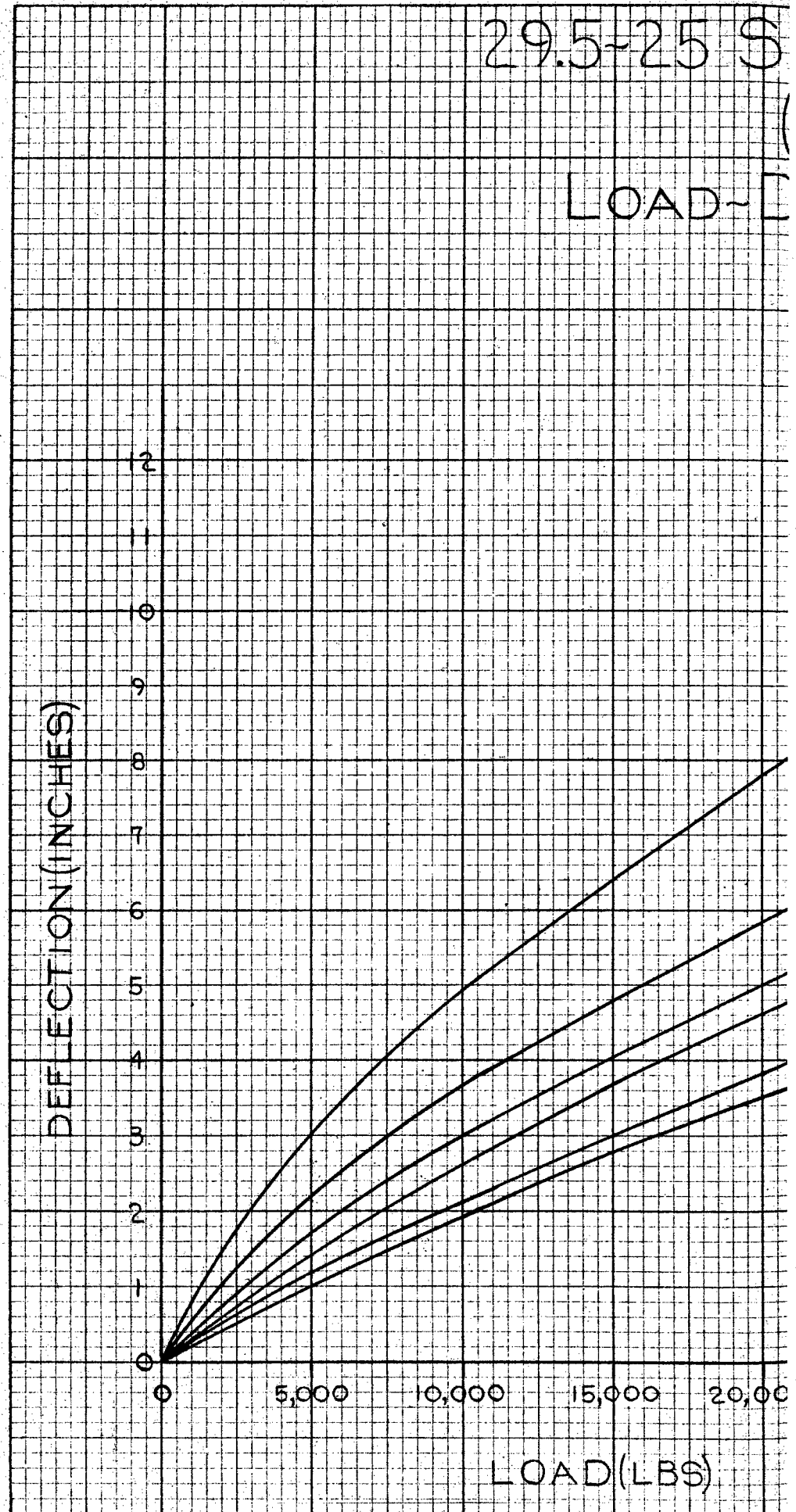
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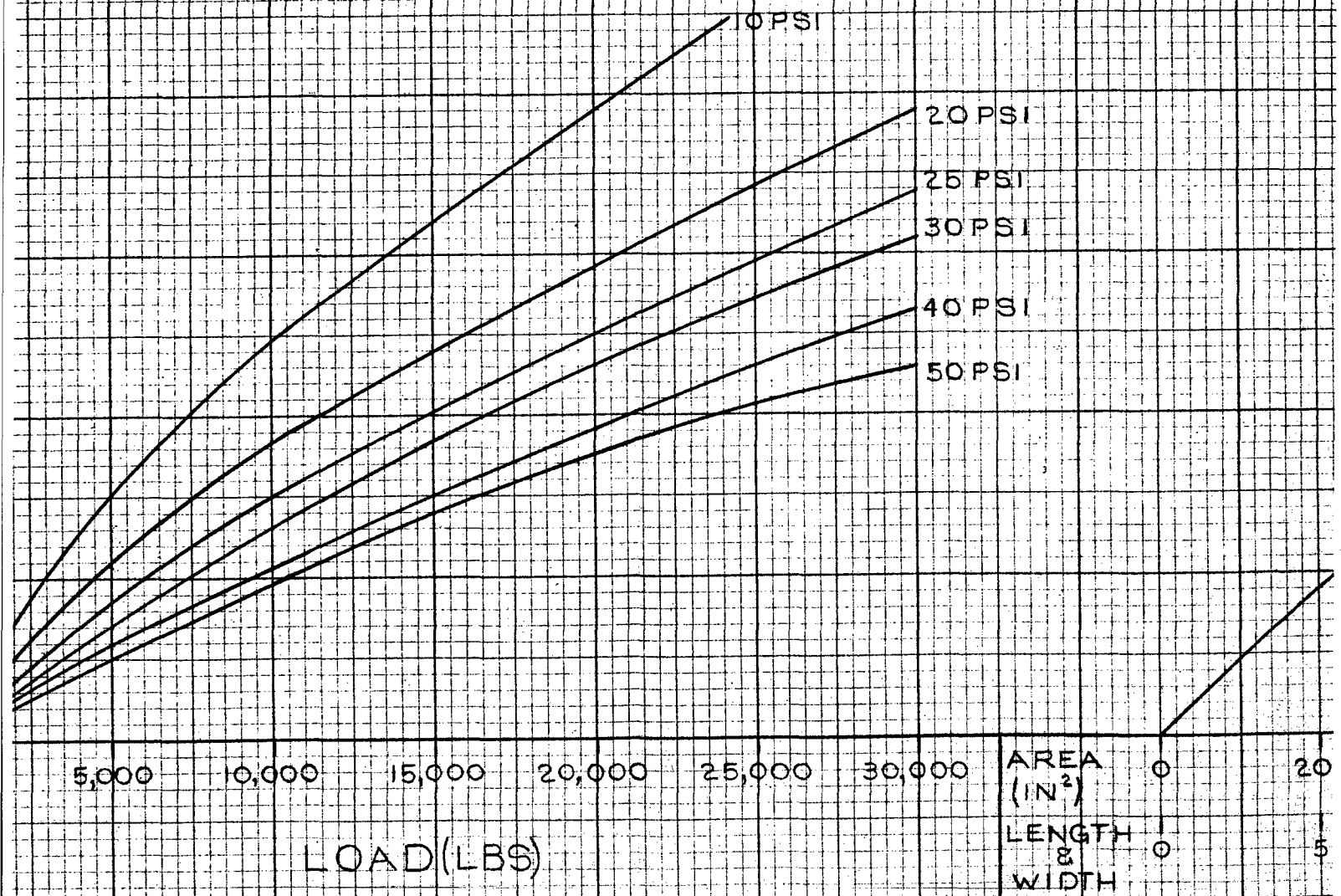
20,000

LOAD (LBS)

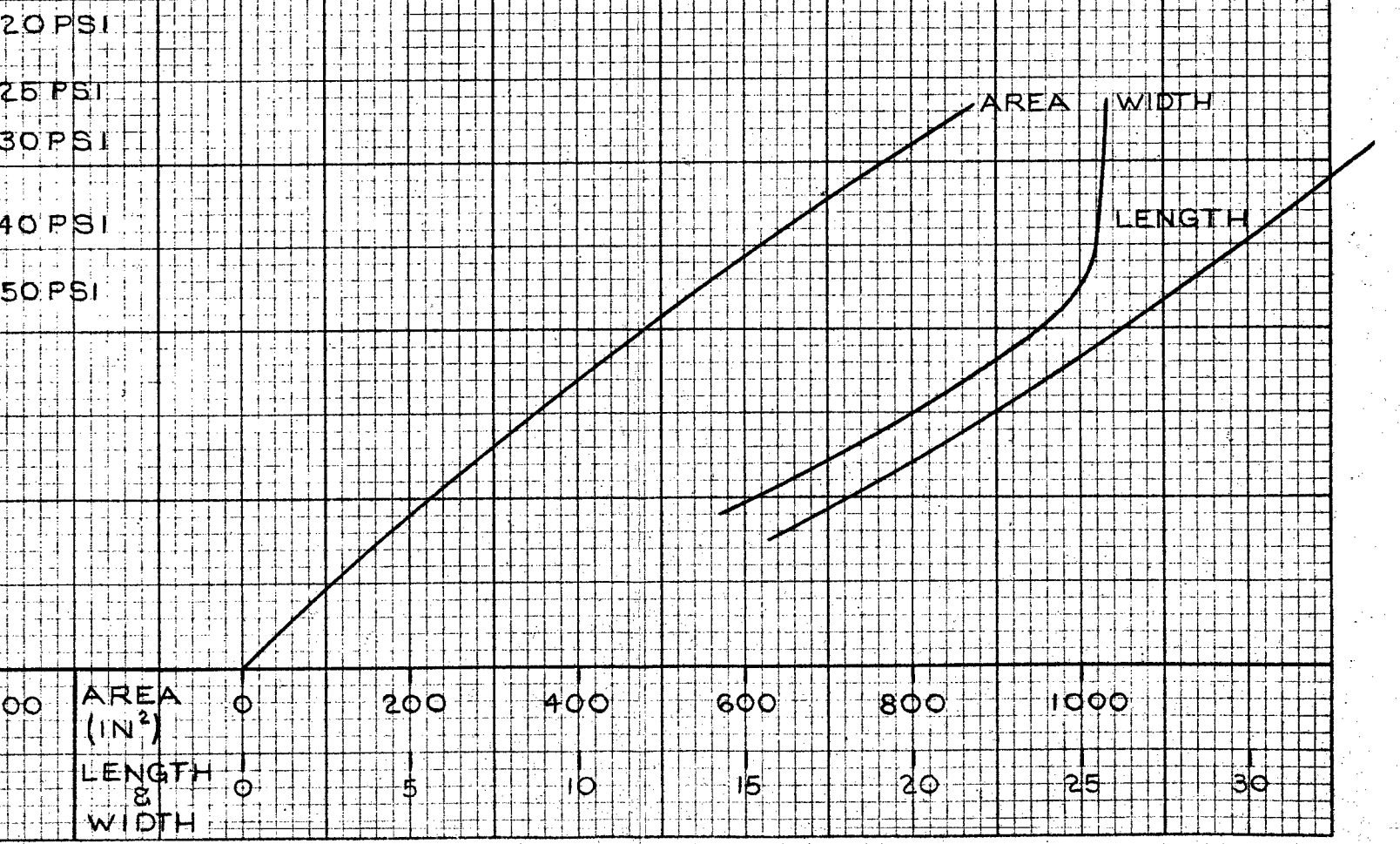


②

# 29.5-25 SUPER GROUND GRIP GC (WITH GROOVES) LOAD~DEFLECTION~CONTACT



# UND GRIP GOER (6) OOVES) N~CONTACT AREA



UNCLASSIFIED

Security Classification

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| 13. ABSTRACT<br><br>Earthmoving tires were specifically developed for use on the GOER vehicle. This development work included the design of various tread configurations and use of maximum feasible synthetic content. Tires were produced in three different tread designs, and two different levels of synthetic content. These tires were then tested for running temperature, traction, and mobility. Durability tests of 40% highway, 40% secondary roads, and 20% cross country were conducted. These tests showed that tires could be produced to provide at least 15,000 miles without any premature failures for this type of service.<br><br>These tires are more suited to the requirements of the GOER Vehicle than any commercially available tire. The major areas of improvement includes the capacity for continuous highway operation and improved performance in mud. |   |   |

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REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

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|---|--------|----|--------|----|--------|----|
|   | ROLE   | WT | ROLE   | WT | ROLE   | WT |
| Rubber Tires<br>Synthetic Rubber<br>Tubeless Tires<br>Non-Destructive Testing<br>Traction Testing<br>Highway Operation<br>Tire Tread Designs<br>Off-Road Mobility |        |    |        |    |        |    |

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